Effects of psychological and social work factors on musculoskeletal pain complaints and headache

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Summary of the thesis

Musculoskeletal pain and headache represent substantial public health burdens, incurring extraordinary financial costs and reducing the quality of life of many. Biomechanical factors have long been acknowledged as risk factors. More recently, psychological and social conditions at work have also gained recognition as important contributors to somatic health. However, available evidence pertaining to this subject is still limited and somewhat inconsistent. One contributing reason may be the selective focus on a few models of psychological and social work factors. Such models are often quite general and unspecific, attempting to cover a broad domain with few factors. Thus, research has so far documented only a narrow range of factors well. Moreover, since the most commonly researched factors are broadly defined, they may conflate dimensions that are differentially related to different health complaints. Furthermore, most prospective studies have been limited in the approach to modeling exposure over time, most frequently assessing the impact of work exposures measured at one single point in time on subsequent health development. Hence, the present thesis sought to cover a *wide range* of *specific* non-physical work factors in order to discover predictors of *neck pain intensity*, *back pain severity*, and *headache severity* two years later. Information about exposure over several time points was utilized to account for the potentially time-varying nature of working conditions.

Subjects were recruited from an ongoing project encompassing a diverse sample of Norwegian employees. Sixteen exposure factors, including two mechanical factors, were studied. In order to determine which factors most robustly predicted the health complaints, several statistical designs were tested. Thus, studies I-III included *cross-sectional regression analyses* comprising all subjects that were invited at each time point (i.e. also subjects that left or entered the participating companies during the follow-up period) and *prospective regression analyses* comprising subjects that were invited at both time points (i.e. employees that remained employed by their respective companies during the follow-up). Hence, somewhat different samples were analyzed within the studies, allowing the assessment of the consistency of observed associations across analyses and samples. Prospective analyses were conducted with exposure modeled both by *baseline exposure levels* and *average exposure levels* across time (i.e. ([T1 + T2]/2) as

predictors of baseline-adjusted health complaints at follow-up. In studies I and II different categories of exposure development from time 1 to time 2 were also studied as predictors, and in study III *cross-lagged* and *synchronous structural equation models* were estimated to compare the tenability of different causal hypotheses. Samples were derived from the same project at different points in time, resulting in the following sample sizes: *Study I*: Cross-sectional sample at T1 (n = 4569) and T2 (n = 4122), and prospective sample (n= 2419). *Study II:* Cross-sectional sample at T1 (n = 5212) and T2 (n = 4722), and prospective sample (n= 2808). *Study III*: Cross-sectional sample at T1 (n = 6421) and T2 (n = 5930), and prospective sample (n= 3574).

Most psychological and social exposures were associated with all health complaints either cross-sectionally, prospectively, or both. The most *robust* and *consistent* predictors of higher neck pain intensity in study I were *role conflict* and *working with arms raised to or above shoulder level*. The most consistent protective factors were *empowering leadership* and *decision control*. The most consistent predictors of back pain severity in study II were the protective factors *decision control, empowering leadership*, and *fair leadership*. The most consistent predictors of more severe headache in study III were higher *quantitative demands* and *role conflict*, and lower *decision control*, *control over work intensity*, and *job satisfaction*. The role of these factors as causal determinants of headache severity was partially supported by cross-lagged models and fully supported by synchronous models, possibly indicating that the effect of the factors takes place over a shorter time period than the two year follow-up period of the study.

For *study IV* prospective analyses were conducted with 1250 employees that had been invited three times and had answered the questionnaire at least twice during a four year period. Five exposure factors were analyzed; *Role conflict, decision control, empowering leadership, social climate,* and *quantitative demands. Group-based trajectory models* (GBTM) were employed to identify clusters of similar exposure reporting over the three time points, and neck pain occurrence was regressed on the resulting exposure groups. Distinct group differences in risk of neck pain at T3 were observed for all factors. For subjects reporting *no pain at baseline*, the risk of new-onset neck pain during the follow-up period was influenced by all factors. For subjects reporting *pain at baseline,* the risk of persistence at T3 was influenced by *role conflict, quantitative demands*, and lack of *decision control*.

In conclusion, some relatively novel factors were identified as predictors of neck- and back pain as well as headache. Most notably, factors such as *role conflict, empowering leadership* and *decision control* appeared more consistently and strongly related to the health complaints than factors that have more often been emphasized in the past, such as quantitative demands, support from superiors, or physical workload. Furthermore, strong indications were observed that the modeling of exposure in cohort studies should not be based on arbitrary categorization or measurements derived from one time point only. The current works should have considerable practical implications as the identified factors were relatively specific and should be more amenable to organizational interventions or improvement efforts than general attempts to reduce “stress” or “demands”.

List of papers

The current doctoral thesis is based on the following papers:

Paper I:

Christensen JO, Knardahl S. Work and neck pain: A prospective study of psychological, social, and mechanical risk factors. Pain 2010;151(1):162-73.

Paper II:

Christensen JO, Knardahl S. Work and back pain: A prospective study of psychological, social, and mechanical predictors of back pain severity. European Journal of Pain 2012;16(6):921-33.

Paper III:

Christensen JO, Knardahl S. Work and headache: a prospective study of psychological, social, and mechanical predictors of headache severity. Pain 2012;153(10): 2119-32.

Paper IV:

Christensen JO, Knardahl S. Time-course of occupational psychological and social factors as predictors of new-onset and persistent neck pain: a three-wave prospective study over four years. Submitted manuscript.

1. Background

1.1. Scope of the problem

Musculoskeletal pain is a common experience across age groups as well as socioeconomic and geographical borders. Pain serves a practical purpose by informing us of ensuing threat and is universally appreciated as essential for survival and adaptation. The life-time prevalence of pain attributed to structures of the spine (e.g. neck- or back pain) has been reported to be 54-80 % (Manchikanti, Singh, Datta, Cohen, & Hirsch, 2009). While most people experience transitory pain during a life-time, making it a common and foreseeable occurrence, persistent pain in absence of identifiable pathology is also relatively common. Such unexplained pain has less obvious adaptive value and represents a persistent large scale public health challenge. A recent survey of 15 European countries reported that 19 % of respondents suffered chronic musculoskeletal pain (more than 6 months) (Breivik, Collett, Ventafridda, Cohen, & Gallacher, 2006). Intractable musculoskeletal pain will often hinder functioning and activity when increased activity levels would have been adaptive. Hence, the suffering as well as the socioeconomic cost precipitated by unexplained pain seems to be out of proportion with the adaptive adjustments it motivates. Musculoskeletal pain disorders remain the main reason for sick leave in Norway, responsible for 34.6 % of cases of sickness benefits paid out from the National Insurance Scheme in 2008 (Brage, Ihlebæk, Natvig, & Bruusgaard, 2010). According to the Norwegian Labor and Welfare Services (NAV) 2 596 218 work days were lost to doctor-certified sickness absence during the last quarter of 2012 (www.nav.no). It was recently estimated that for a Norwegian company the economic cost of one employee being on sick leave for one week is 13000 Norwegian kroner, excluding the cost of salaries that must be paid out by the company during the first 16 days of a sick leave occurrence (Hem, 2011). Thus, when 2 596 218 work days are converted into 519 244 five day working weeks, the economic cost of certified sick leave due to musculoskeletal disorders for the last three months of 2012 were approximately 6.75 billion kroner, in addition to salaries for the first 16 days of sick leave before The National Insurance Scheme takes over. Also, costs must be assumed to be incurred by short term absences that do not require certification by a doctor as well as productivity loss from suboptimal health that does not result in absence. Obviously, the costs for both individuals, companies, and society are considerable and any knowledge that facilitates the reduction of these types of health complaints has great potential to improve public health.

Headache encompasses many types and possible pathophysiologies and is not considered a musculoskeletal complaint. Nevertheless, it is often associated with muscle pain and is responsible for substantial suffering on a population level. The prevalence of headache is comparable with musculoskeletal complaints, with recent investigations suggesting a point prevalence approaching 50 % in the general adult population (Stovner et al., 2007). Headaches are more common at a younger age, and may be particularly relevant for the working population. The most common form of headache, tension-type headache, remains an unspecific health complaint that exhibits an unknown pathogenesis.

Work is a central part of life to most people and can fulfill such diverse purposes as subsistence, self-realization, and the need for social contact. Because of this significance and the fact that so much time is spent at work, it seems reasonable to assume that events that occur within the work context are influential for employee health in both negative and positive ways. Much effort has been devoted to identifying work factors associated with elevated risk of pain disorders. Given the pervasiveness of musculoskeletal health problems and the degree of suffering associated with them, little controversy surrounds the notion that diminishing musculoskeletal pain is a vital public health concern and that the workplace is one suitable arena in which to face this challenge. There is however slightly more controversy regarding the appropriate targets of intervention for the attainment of this goal. Traditionally, the assumption has seemed widespread that the most important insights relevant to pain management can be derived from investigation of mechanical loads. However, the problem of pain persists despite progresses made in such investigations. Indeed, it has been suggested that musculoskeletal pain is actually more common now than it was half a century ago (Harkness, Macfarlane, Silman, & McBeth, 2005; Morse et al., 2005).

Biopsychosocial approaches have added valuable insights to the understanding of the problem of pain. They acknowledge that pain and suffering should not and cannot be constrained to regard only the cases which can be fully ascribed to the physics of somatic tissue. The importance of taking into account psychological and social aspects has been underlined and the ultimate goal is to attain a more comprehensive understanding of the multifactoriality of the pain experience and its causes, consequences, and covariates. Approximation of that goal would bear the potential to diminish much avoidable suffering.

The interest in expanding the approach to the study of work-related pain has motivated many studies to also investigate non-physical aspects of work. The majority of these studies have tested factors of the Job strain model of Robert Karasek (Karasek et al., 1998). Some psychological/social work factors have thus been shown to be relatively consistently related to different complaints, such as e.g. high job demands and low decision control with neck- and back pain (Bongers, IJmker, van den Heuvel, & Blatter, 2006; Walker-Bone, Palmer, Reading, & Cooper, 2003; Ariëns, van Mechelen, Bongers, Bouter, & van der Wal, 2001; Malchaire, Cock, & Vergracht, 2001; da Costa & Vieira, 2010a; Hoogendoorn, van Poppel, Bongers, Koes, & Bouter, 2000; Macfarlane et al., 2009). However, critics have suggested that this research is not nearly as persuasive as often claimed (Hartvigsen, Lings, Leboeuf-Yde, & Bakketeig, 2004). There is still a lack of research with designs conducive to causal interpretation and the number of factors that have been thoroughly investigated is too limited to warrant general conclusions pertaining to the totality of "the psychosocial work environment". Naturally, results of individual studies pertain to specific factors. Nevertheless, debate has often seemed to regard the relative contribution of "psychosocial" and "physical" factors. However, such debate implies that the sum impact of both domains has been determined, which seems an unreasonable contention. General conclusion regarding the relationship of psychological and social work factors with pain complaints remains difficult because previous research has studied a limited range of factors. Also, the factors that have been studied are often rather broad, e.g. comprising different types of psychological challenges into one dimension of "job demands".

The aim of the current thesis was to elucidate a *broader range* of *more specific* psychological and social work exposures than what has been common in previous studies. This should provide a useful addition to existing knowledge and highlight the utility of a comprehensive approach when studying the multifactorial domain of "the psychosocial work environment". The factors investigated should be specific enough to allow focused intervention- and improvement efforts in organizations. Also, most previous prospective studies have utilized two-wave panel designs without taking exposure development across time into account. Therefore, the papers of the current thesis underscore the importance of conducting additional full panel studies that take exposure development over time into consideration in order to gain solid knowledge about the ways in which non-tangible characteristics of the working situation may influence employee health over time.

1.2. Pain

A comprehensive review of the history of pain research is far beyond the scope of the current thesis. However, some background may be useful to provide a context for the current works and to elucidate some of the ways in which psychology has been relevant to the understanding of the pain problem.

1.2.1. The current definition of pain

Pain is universal since (almost) everyone is capable of experiencing it and yet it is inherently private since it is only immediately available to the person experiencing it. It is amenable to functionalistic description since it is so clearly associated with conditions that put the organism at risk. It seems highly reasonable that it would serve an adaptive purpose for living organisms to evolve an apparatus for detecting potential threat – pain conveys information that provides a basis for actions that prevent harm or exacerbation, thereby increasing the likelihood of survival. Painful experiences motivate withdrawal from harmful situations, immobilization of injured body parts to allow efficient healing, and aversion to similar situations in the future. However, the pain system is not a noise free signaling system. It can also indicate danger when none is present and sometimes it captures attention to such an extent that harm results rather than desists. This seems to be the case with chronic pain patients, for which pain no longer serves any clear "purpose" but instead has a severe adverse and maladaptive impact on life.

The widely cited definition of the International Association for the Study of Pain (IASP) states that pain is "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage" (International Association for the Study of Pain Task Force on Taxonomy, 1994). The emphasis on subjective emotion is noteworthy, as is the affirmation that although tissue damage is closely related to pain it is not equatable with it or a necessary precondition for pain to exist. Although pain in this context pertains to somatic pain the role of subjectivity and emotion as integral to the pain phenomenon is acknowledged and emphasized. There are substantial individual differences in pain as a response to similar stimuli and pain may even exist in absence of physical stimuli (Andrasik, Flor, & Turk, 2005). Hence, it has proved difficult to adequately describe the characteristics of pain by confining it to the biological level of analysis.

1.2.2. Classifications of pain

There are several useful ways of classifying pain. In 1968 Ronald Melzack and Kenneth Casey proposed a classification of the pain experience that has become highly influential (Melzack & Casey, 1968). This classification refers to aspects of the subjective *experience* of pain, describing it by three components – the *sensory-discriminative* (e.g. the intensity, location, and duration), the *affective-motivational* (e.g. degree of unpleasantness and desire to avoid the assumed cause), and the *cognitive-evaluative* (e.g. the appraisal, meaning, and thoughts about the pain). Important to this distinction was that there was an explicit qualitative distinction that analytically separated features of pain, explaining how pain can be modulated by influencing either of these aspects. It was clear that the magnitude of an external stimulus was considered only one of many determinants of the conscious pain experience and Melzack and Casey encouraged the consideration of motivational-affective and cognitive-evaluative factors in the treatment of pain conditions.

Another example of an analytical classification of pain is Loeser and Melzack's (1999) four broad categories that describe processes involved in pain; *nociception*, *perception*, *suffering*, and *behavior* (Loeser & Melzack, 1999). *Nociception* refers to nervous system mechanisms that are triggered by certain types of stimuli that have the potential to result in the perception of pain. The receptors that convey such information, the *nociceptors*, convert certain types of input (e.g. heat, mechanical force, hypoxia, chemical stimulation) into nerve impulses that travel from the peripheral nervous system via the spinal cord and terminate in the brain. The translation of stimuli into nerve impulses is called *transduction*. When arriving in the brain the nerve impulses go through the thalamus and project into the somatosensory cortex. After activation of a nociceptor several neurobiological mechanisms exist that modulate the resulting pain experience by inhibiting or facilitating transmission of the nerve impulses (Patel, 2010). Some of these mechanisms involve transmitters and pathways, such as the endogenous opioids and serotonin, which are also associated with mood regulation and psychopathology such as depression and anxiety (Bair, Robinson, Katon, & Kroenke, 2003). *Perception* of pain is closely related to nociception in that is most often initiated by nociceptive activity. However, due to the complex chain of events that intervenes between the nociceptor and the cerebral cortex, there is no simple one-to-one relationship between the intensity of the nociceptive stimulus and the perceived pain, and it is also possible for pain to occur without nociception (Loeser & Melzack, 1999). *Suffering* refers to the negative emotional experience that accompanies the perceived pain. It remains difficult to distinguish the suffering that is a direct function of nociception from that which may be contributed from other sources, partly due to the fact that all suffering is described in terms of pain. Loeser and Melzack (1999) maintain that "not all suffering is caused by pain, but in our medicalised culture we describe suffering in the language of pain" (p. 1608). *Pain behaviors* refer to observable behavioral consequences of tissue damage, such as grimaces, limping, or screaming. These are objective, observable, and quantifiable indicators of a pain experience taking place, but the extent of the pain itself is only inferred from such observation, and they do not allow easy access to the inherently private experience of pain. Individual as well as cultural differences are likely to affect the variation in expressions of equivalent subjective pain experiences.

Another important distinction is based on the duration of pain and distinguishes between *transient, acute,* and *chronic* pain (Loeser & Melzack, 1999). *Transient* pain is short-lasting and initiated by stimuli that do not cause tissue damage. It provides motivation to avoid certain stimuli *while* they are a threat and *before* they become harmful. *Acute* pain may occur after an injury but goes away relatively quickly, when the injury is resolved and healing has started.

Chronic pain, on the other hand, is pain that persists after the expected healing period, often with no known proximal cause or a low level of underlying pathology that does not seem sufficient to explain the extent of the subjective pain condition (Turk & Okifuji, 2001). It is difficult to determine what duration of a complaint suffices for it to qualify as "chronic", and most attempts at classifying chronicity by a specific duration seem inherently arbitrary. Different alternatives have been proposed, with three or six months being the most common (Turk & Okifuji, 2001). Chronic pain has also been defined as pain that persists beyond the *expected* healing period (Turk & Okifuji, 2001). Most people experience occasional incidents of moderate acute pain that does not exceed coping abilities but are viewed as natural side-effects of life as long as a proximal cause can be identified. Chronic pain, however, may be perpetuated by unknown factors not directly related to the original cause of the pain and can cause severe distress and adversity for the person experiencing it. For chronic pain patients the pain has become the "disease" rather than a symptom of a disease. If pain is to be viewed as an alarm system, for chronic pain patients alarm bells are constantly ringing but the threat that they signify remains hidden and unmanaged.

1.2.3. A brief history of pain

The history of the study of pain has demonstrated an increasing interest in the psychology of pain. Among the major motivations for incorporating psychological factors in the scientific scrutiny of somatic pain is the observation that tissue damage severity corresponds with pain severity to a much more modest extent than first expected. Early theories of pain focused more exclusively on the physiological signals evoked by peripheral stimuli and transmitted to the brain by the nervous system. The brain was assumed to unambiguously interpret these signals as pain of a severity directly determined by the intensity of the stimuli (Melzack, 1996b). During the 17^{th} century René Descartes formulated the first well known attempt to apply the scientific method to the study of pain. Inspired by the scientific revolution of his time Descartes wished to describe the functions of the human body by a set of mechanistic principles derived from physics, and pain was conceived of as a specific biological pathway with spatiotemporal presence. Thus, the observable aspects of the pain process were given analytic priority. Inspired by this view *specificity theory* emerged and was elaborated during the 19^{th} century (Melzack & Wall, 1965). Specificity theory viewed the pain system as a specific signal system that unambiguously encodes specific stimuli related to tissue damage, transmits these signals through specialized nerve fibers, and thereafter decodes these stimuli in a specialized pain center in the brain. Thus, this theory virtually equated the stimuli with the resulting pain experience (Melzack, 1996a). It did not yet consider the possibility of interference between encoding and decoding, such as “downstream” modulation of pain signals by cognitive factors or anxiety. The brain was considered a “passive” recipient and decoder of encoded information. Specificity theory was useful in elucidating the basic mechanics of pain, but failed to account for chronic pain or the substantial individual differences in the response to equivalent stimuli. This view of pain inspired many unsuccessful treatments of chronic pain such as neurosurgical lesions to disrupt the presumed pain signal traffic (Melzack, 1996a). Also, reported pain in absence of (observable) organic pathology was considered mental illness and assigned to equally unsuccessful psychiatric treatment (Melzack, 1996a). Nevertheless, specificity theory may perhaps appear a more plausible theory of pain to the lay public than contemporary “biopsychosocial” views. This may be partly because it is useful in explaining acute pain caused by known trauma, but for chronic pain sufferers the notion that pain equals tissue damage may not necessarily work well.

In recognition of the limitations of specificity theory, *pattern theories* postulated that no specific pain fibers existed. Instead, they suggested a variety of interacting mechanisms to explain different features of pain that specificity theory failed to account for (Melzack & Wall, 1965). Generally, these theories postulated that pain results from specific *patterns* of nerve activity rather than from specific nerves. For instance, the persistence of pain after healing has occurred was proposed to stem from a reverbatory circuit in the dorsal horns, and spatiotemporal summation of nociceptive signals in the dorsal horns was proposed as a crucial determinant of the pain experience (Melzack, 1996b). Pattern theories anticipated later developments in many ways but were rather fragmented and vague and, as with specificity theory, they did not consider the modulation of pain at the level of the brain (Melzack, 1996b).

In 1965 Melzack and Wall proposed a new theory to account for the shortcomings of previous ones – the *gate control theory of pain* (Melzack & Wall, 1965). This theory proved pivotal and highly influential in the subsequent development of pain theory. Inspiration for the gate control theory came from Ronald Melzack’s observations of the behavior of dogs that had been raised in social and sensory isolation (Melzack, 1996a). When released from their cages he noted that these dogs, experiencing a multitude of novel stimuli from their environment, seemed relatively insensitive to noxious stimuli and less prone to avoid them. Therefore, he conjectured that the adverse stimuli were not automatically relayed to attention but entered in competition with other stimuli. The gate control theory rejected the view of the pain process as a simple one-way signal and posited a more complex process involving traffic both “upstream” to the brain and “downstream” from the brain. In short, Melzack and Wall proposed a “gating” mechanism in the dorsal horn of the spinal cord that had the capacity to “open or shut” in order to facilitate or inhibit nociceptive traffic. These “gates” were proposed to be controlled by collaterals from other afferent nerves conducting touch and other sensory modalities as well as by nervous pathways descending from the brain. This highlighted the dependence of pain processing on processes at “higher levels” of the nervous system and provided a plausible explanation of the influence of thinking and emotion on the pain experience.

One of the most important insights the gate-control theory presented was that many events take place between a potentially painful stimulus and the resulting experience of pain. Many of these events are susceptible to manipulation by external influences and thus this process is much more flexible and plastic than what was commonly assumed. The current distinction between nociception and pain highlighted in the IASP definition of pain reflects a contemporary recognition of this. It is known that nociceptive input is not invariably determined to become pain, and that when it does indeed, pain intensity is not unequivocally determined by stimulus intensity. However, the monumental influence of this theory may still not always be translated into practice. In a 1999 “overview of pain” Loeser and Melzack noted that “local and regional anesthesia can prevent nociception from becoming pain, but so can downstream modulation, as proposed in the Melzack-Wall theory. Such issues are routinely ignored by physicians” and that “many physicians and patients do not realise that pain can occur without nociception” (Loeser & Melzack, 1999, p.1608).

Ronald Melzack later proposed the “*neuromatrix theory of pain*” (Melzack, 1999), which further broadens the scope. This theory was inspired by the conundrum of "phantom limb pain", i.e. pain that is perceived to be originating from a part of the body that does no longer exist. It illustrates that pain cannot (in all cases) be a simple "bottom-up" process since the part of the organism to which pain is ascribed does not exist. Melzack proposed that pain is a multidimensional experience generated by a "neurosignature" that exists in the brain (Melzack, 1999). This “neurosignature” was thought of as an individual characteristic, a “matrix” consisting of typical patterns of neural activity. The combination of activities in this system determines the pain experience. Over time this matrix pattern may change as a consequence of diverse external influences. The input systems implicated were mainly thought to be the thalamocortical, somatosensory, and limbic systems. A central feature of this theory was that it explicitly postulated a mechanism by which emotions and cognitions could influence pain, since somatic sensory input was only one (albeit important) of several possible inputs that could generate pain by feeding information into this neural network (Melzack, 1999). The neuromatrix theory was thus thought to be useful in explaining chronic pain and Melzack has proposed a central role for “stress” in influencing the neuromatrix (Melzack, 1999). Although it has become common to refer to the “pain matrix”, Melzack originally proposed a general theory of the neuromatrix as a network of neural activity in the brain that was responsible for representing “the body-self” and that was capable of producing output that was experienced as pain. Currently, definitions of the “pain matrix” seem to vary. For instance, while some consider the pain matrix to be a collection of structures in the brain that specifically process aspects of pain, others believe that the matrix should refer to the pattern of activation, i.e. the interaction of processes itself, that combine in such a way that the pain experience emerges (Iannetti & Mouraux, 2010).

1.2.4. Biopsychosocial perspectives

In summary, early theories of pain were stimulus-centered while more recent theories encompass a wider range of influences and acknowledge the multifactoriality of pain. Analogously, there is a distinction between a *biomedical* and *biopsychosocial* approach to pain (or health in general). In 1977 George Engel stated that “the traditional biomedical view, that biological indices are the ultimate criteria defining disease, leads to the present paradox that some people with positive laboratory findings are told that they are in need of treatment when in fact they are feeling quite well, that is, they have no ‘disease’. A biopsychosocial model which includes the patient as well as the illness would encompass both circumstances” (Engel, 1977, pp. 132-133). Thus, biopsychosocial approaches emphasize the multidimensional complexity of health problems and call for approaches that deal with the totality of them. In approaching the problem of pain this seems particularly relevant since subjective pain report is so often the only indicator of disease. Nevertheless, Andrasik, Flor, and Turk (2005) maintain that the prevailing model of chronic pain is still "biomedical" and concerned with signals transmitted from peripheral tissue to the central nervous system (Andrasik et al., 2005). This "traditional" approach runs into difficulties when attempting to explain (1) pain in absence of identifiable pathology, (2) pathology in absence of pain (3) individual differences in treatment response (4) the relative inadequacy of potent pain-relieving medication over time, and (5) the unexpectedly weak relationship of pain severity with impairment and disability (Andrasik et al., 2005). In spite of apparent progresses in biomedical science and pharmacology the problem of pain is very far from extinct.

Biopsychosocial approaches to pain oppose the earlier concepts of pain as either *somatogenic* or *psychogenic* (Andrasik et al., 2005). The diversity of how pain presents is rather accounted for by the complex interaction of factors at both the biological, social, and psychological level. If "objective findings" in the form of identifiable organic pathology were the only criterion upon which to base a judgment about health, the majority of those in need of healthcare due to musculoskeletal pain would have to be classified as "healthy". Nevertheless, disability caused by unexplained pain (e.g. non-specific low back pain) is a persistent worldwide problem even in developed countries where physical, biomechanical exposure is assumed to have considerably diminished over time, and it is very common that acute, readily explained back pain transitions into persistent, medically unexplained pain (Olaugun & Kopf, 2010). There is of course a distinction between "unexplained" and "inexplicable" but the fact that so many suffer from conditions that cannot be adequately explained at the biomedical level warrants the inclusion of the psychological and social levels of analysis in the elucidation of the problem.

1.3. "Stress"

The influence of non-physical work exposures on health is frequently discussed under the heading of "work stress" or similar terminology that includes the word "stress" (see e.g. (Chandola et al., 2008; Kivimäki et al., 2006; Mäki et al., 2007; Sjösten et al., 2011; Bosma, Peter, Siegrist, & Marmot, 1998; Bonn & Bonn, 2000). Often, specific psychological and social factors (most often "job demands" and "decision control") are referred to as "measures of stress". Also, many studies report effects of "mental stress" , "perceived psychological stress", "psychosocial stress", and similar (see e.g. (Ariens et al., 2001; da Costa & Vieira, 2010a)). Unfortunately, the term "stress" is widely applied in both academic and everyday language to characterize a variety of phenomena and circumstances. It is often used to describe workload ("there is a lot of stress at work") or illness ("I suffer from stress") and seems to be interchangeably applied to both working *conditions*, individual *responses* to such conditions, and the process between. Since any study pertaining to psychological and social work factors may be labeled "stress research" a brief discussion seems warranted to clarify the relevance to the current subject matter.

The first important technical use of the term "stress" is said to have come from the 17th century physicist-biologist Robert Hooke, who applied it to describe the impact of physical forces on man-made structures (Lazarus, 1993). In this usage "load" would denote the weight of an object, "stress" would be the area the load pressed down on, and "strain" would be the resulting deformation. In the 20th century the study of physiological correlates of "psychological stress" became popular, with Walter Bradford Cannon as a major early influence (although the routine application of the "stress" term to these phenomena came later). As a physiologist inspired by social psychology, Cannon became interested in autonomic nervous system activity associated with emotions and environmental challenges (Cooper, 2008). He formulated a theory to explain acute physiological responses during "emotional excitement" such as pain and fear; what has come to be known as the "fight or flight"-response (Cannon, 1922). Central to this thinking was the concept of *homeostasis*, a term coined by Cannon to describe the mechanisms of what had earlier been called the "milieu interieur" by the French physiologist Claude Bernard (Selye, 1973a). The concept of the "internal environment" implies the dynamic internal regulation of processes necessary to sustain the organism independently of the environment that is external to the body. Thus, homeostasis refers to the "normal" fluctuation of states within an organism. The external and internal environments interact when emotions induced by challenging situations disrupt homeostasis by initiating the secretion of hormones, such as adrenaline, that facilitate actions that are conducive to adaptation.

Hans Selye later described what he called "a syndrome produced by diverse nocuous agents" that provided the empirical basis for his theory of the "general adaptation syndrome" (GAS) (Selye, 1998). In short, the general adaptation syndrome described hormonal responses to "stressful stimuli" and delineated a number of physiological changes that occur with acute and prolonged exposure to certain types of stimuli [35]. The GAS was seen as a general response to any kind of environmental demands. This view has later been challenged, and also nuanced by Selye himself. Mason has argued that although a general physiological reaction occurs in the presence of a wide variety of different kinds of stimuli these stimuli are usually accompanied by certain psychological and emotional events (Mason, 1971). He pointed out that previous research had neglected the inherent difficulty of isolating nocuous physical stimuli from their psychological concomitants. Thus, the non-specificity of the hormonal response to different challenges could be a result of the similar emotional reactions to these challenges.

The term "stress" was later coined by Selye to denote "the non-specific response of the body to any demand made upon it" (Selye, 1973b, p. 1). Notably, this definition identifies stress as a response rather than a stimulus, and does not specify any threshold above which "stress" can be said to have occurred. Rather, it is seen as the general process of adapting to fluctuating environmental demands. This concept of stress has been criticized for being too general and ambiguous. Selye has stated that "complete freedom from stress is death" (Selye, 1973b, p. 346) and maintained that "it cannot be avoided: no matter what you do or what happens to you, there arises a demand to provide the necessary energy to perform the tasks required to maintain life and to resist and adapt to the changing external influences" (Selye, 1973b, p. 346).

From the 1960s Richard Lazarus played a central role in emphasizing and elucidating the roles of cognition in "stress" by emphasizing *appraisal* and *coping* (Lazarus, 1993). Reflecting the "cognitive revolution" in psychology, Lazarus aimed to surpass the "stimulus-response" paradigm by bringing attention to the psychological perception of the *contents* of demanding situations and the role of cognitive processes in determining the outcome of them. This acknowledged the significance of subjectivity and meaning as well as "objective" behavioral and situational aspects of environmental challenges. The individual actively appraises and evaluates the environment to derive meaning and evaluate what poses a challenge. Lazarus and Folkman described this process as consisting of *primary* and *secondary* appraisal (Lazarus & Folkman, 1984). During the first stage of primary appraisal the meaning of an event is evaluated to be "irrelevant", "benign", or "stressful". If evaluated as "stressful" the individual further evaluates the event as "harm" if the adverse outcome has already occurred, "challenge" if the mastery of it is expected to result in positive change, and "threat" if the event is perceived as likely to cause harm. Furthermore, during secondary appraisal the individual evaluates which options and resources are available to meet the demand. Thus, Lazarus and Folkman underscored the role of cognition and active interpretation of observed and experienced events in determining the psychological significance of environmental challenges. This emphasis on the inherent subjectivity of "stress" is evident in contemporary discussions of psychological work exposures. For instance, a 2000 article in The Lancet offered the following definition: "Stress, in essence, is a feeling of doubt about being able to cope, a perception that the resources available do not match the demands made " (Bonn & Bonn, 2000, p. 1). In this case "stress" is defined as a feeling.

Lazarus maintained that "the study of stress has been plagued by an inconsistent and potentially confusing use of terms to denote the variables of the stress process" (Lazarus, 1993, p. 3). Selye, who launched the term, was Hungarian, and Rosch has reported that "Selye once complained to me that had his knowledge of English been more precise, he would have gone down in history as the father of the "strain" concept" (Rosch, 1998, p. 4). To deal with this confusion Selye launched the term "stressor" to separate cause from effect. Nevertheless, in studies of psychological and social work factors the term "stress" seems to have been interchangeably applied to both environmental factors and psychological reactions to them. For instance, the often used measures of *job demands* and *decision latitude* are frequently referred to as measures of "job stress" (see e.g. Tsutsumi, Kayaba, Theorell, & Siegrist, 2001) but are purported to reflect environmental characteristics, i.e. "stressors", that may *induce* mental strain (Karasek, 1979). Many studies report the effects on health of "perceived stress" or "mental stress", or even the effects of work factors on "stress symptoms". It is often unclear whether such concepts pertain to the perceived exposure to certain conditions or the resulting mental and emotional processes. For instance, a measure of "work stress" may collect information about work amount (i.e. an appraisal of environmental demands) as well as feelings of being overwhelmed by a high workload (perhaps an appraisal of the degree to which the demand is "stressful" and whether it is a threat or a challenge). There may be an important difference between what an individual considers a high workload (perhaps heavily influenced by standards based on norms, conventions, and job descriptions) and how that individual responds to that same workload (degree of distress). Although both concepts are subjective, in the first case one would be measuring perceived workload and in the latter one would be measuring the psychological reaction to this perception. This apparent juxtaposition of cause and effect is even more pronounced in everyday language, where "stress" seems to routinely connote conditions that a person is subjected to or the response of the person to these conditions; when someone reports being "stressed" it is fairly open to interpretation whether this person claims to have an excessive workload or is describing their own inability to cope. For scientific studies based on self reports of "stress" (especially single item measures) this represents a problem since it implies that employee evaluations of "work stress" could reflect a mixture of modifiable working conditions ("demands") and less modifiable worker responses ("mental strain").

In reviewing the use of the "stress" concept, Pollock has argued that it is so conflated with different meanings that it should be abandoned in favor of the specific concepts that it subsumes (Pollock, 1988). He concluded that "where the nature of what is stressful depends on subjective perception, and thus varies from one person to another, it becomes impossible to arrive at any precise definition of the term, except by the nature of its effects, by which it does indeed seem in danger of being defined. I suggest that the term itself has become so vacuous that it represents an obstacle rather than an aid to research, and that further investigation of the relationships which the stress theory attempts to elucidate would get on better without it" (p. 390). It has been shown that survey respondents draw on a wide range of meanings when interpreting items that make use of the term "stress", varying from employees' responses to task characteristics and the work environment itself (Jex, Beehr, & Roberts, 1992). Thus, it may be that the elusiveness of the concept of "stress" is a threat to the interpretation of studies employing it.

1.4. Psychological and social work factors

The notion that psychological factors can cause and modulate pain is fairly well established and uncontroversial. Logically, then, it would seem almost obvious that an employment situation can influence the subjective experience of somatic health. The work arena represents a fundamentally important part of life to most people, both in providing the necessary resources to sustain a satisfying life and also as a potentially meaningful activity that forms social identity (Ashforth & Mael, 1989). Also, since most employees spend much of their waking time in the work context carrying out work tasks it is a significant source of psychological influences. Hence, work is psychologically salient and employees are under the influence of it for extended periods of time.

1.4.1. "Psychosocial work factors"

The scientific investigation of effects of non-tangible work factors on the individual are usually conducted under the heading of "psychosocial work factors" or similar forms such as "occupational psychosocial factors" or "the psychosocial work environment". The term "psychosocial" is avoided in the current thesis. There seems to be no agreed upon definition of the term and it is rarely explained in scientific studies. Similarly to "stress", it appears to be frequently used in epidemiology to refer both to causal precursors of ill health, mediating factors and contexts, and outcomes. For instance, Martikainen and coworkers asserted that the "unspecified use of 'psychosocial' – something of which we are equally guilty – is likely to degrade the use of the term. It refers to everything and nothing in particular" (Martikainen, Bartley, & Lahelma, 2002, p. 1091). In occupational health studies dealing with psychological work factors the term psychosocial has become practically synonymous with "demand-control", and one problem therein may be the apparent assumption that all "psychosocial factors" are of the same kind. In much the same way as "stress", "psychosocial" may have become a "buzzword" that may sometimes obscure rather than inform. Although the term is rarely accompanied by a definition, some exceptions can be found. One definition that has been proposed for "psychosocial stressors" is "nonphysical aspects of the work environment that have a psychological and physiological impact on the worker" (Warren, 2001, p. 1299). This definition ascribes psychological effects to the influence of the environment. Another definition states that a psychosocial factor is “a measurement that potentially relates psychological phenomena to the social environment and to pathophysiological changes” (Hemingway & Marmot, 1999, p. 1460). It almost seems as if “psychosocial” *per definition* is tied to adverse health. It is unclear what a corresponding factor is to be considered if its “potential” for pathophysiological modulation cannot be demonstrated. These definitions seem to carry circular components and involve a number of a priori assumptions about the interaction between social, psychological, and biological factors. This may not be seen as a major concern in the daily use of the term, but it becomes a problem when discussion turns towards the more general discussion of whether “psychosocial factors” influence somatic health or not. Many assertive opinions regarding this topic seem to be based on global views of the relevance of “psychosocial factors”, despite only a few such factors having been consistently studied. The term is avoided in the current thesis since some of the studied factors refer to perceptions of the social environment while others deal with task demands or work content. In general, the factors studied herein are of interest because they may influence the individual psychological level. That is, social factors are assumed to be of significance to the extent that they have psychological consequences (Martikainen et al., 2002) and influence employee perceptions, emotions, and behaviors.

1.4.2. Job strain

It is common to refer to “strain” in general terms as any consequence of adverse work exposures. However, the term “job strain” also has a specific meaning defined by the *job strain model* of Robert Karasek (Karasek, 1979). This model is by far one of the best known and most frequently studied models in occupational health psychology. A brief discussion of this particular theory is warranted since much of the following will refer to it. It is also known as the *demand-control* model since it focuses on the relationship between job demands and the control of the worker over resources with which to satisfy these demands. The job strain model has dominated research on the health outcomes of “psychosocial work factors”. Many studies that investigate the factors of this model are reported under the heading of "psychosocial factors", or – in even more general terms – "*the* psychosocial work environment". Karasek formulated this model to bring together two traditions in occupational health psychology that each focused exclusively on either decision latitude or “job stressors” (Karasek, 1979). According to Karasek this resulted in an incomplete understanding of conditions under which strain occurs, which could account for inconsistencies of previous research. According to this view, a simultaneous consideration of both demands and control is necessary to gain a comprehensive understanding of the health-relevant aspects of non-physical working conditions. Based on the different possible combinations of dichotomized demand- and control measures four different *types* of jobs were classified: (1) “Passive jobs” (low demands/low control), (2) “Low strain jobs” (low demands/high control), (3) “High strain jobs” (high demands/low control), and (4) “Active jobs” (high demands/high control). High strain jobs were hypothesized to be unhealthy and active jobs were assumed to be healthy. The *interaction* hypothesis is crucial to the model – high demands are not necessarily unhealthy, but can, given the right conditions, be invigorating and stimulate healthy behaviors both on and off the job (Karasek, 1979). Interestingly, many if not most studies utilizing the Job strain measurement instrument (Karasek et al., 1998) for the task of explaining musculoskeletal health seem to have estimated the main effects of job demands and decision latitude separately. Perhaps mixed results are to be expected then, considering that Karasek originally suggested the separation of these factors as the very reason for inconsistencies in previous research. In the original 1979 article about the Job strain model he stated that it “predicts that mental strain results from the interaction of job demands and job decision latitude. The model appears to clarify earlier contradictory findings based on separated effects of job demands and job decision latitude. The consistent finding is that it is the combination of low decision latitude and heavy job demands which is associated with mental strain” (Karasek, 1979, p. 285).

1.4.3. Psychological and social work factors as antecedents of somatic pain complaints

1.4.3.1. Neck- and back pain

The field of occupational health psychology has been well served by some general models that have been ambitious in attempting to comprehensively represent the most important psychologically relevant aspects of work, such as the models of Job strain (Karasek, 1979), effort-reward imbalance (Siegrist, Siegrist, & Weber, 1986), and organizational justice (Elovainio, Kivimaki, & Vahtera, 2002). The Job strain and effort-reward imbalance models in particular attempt to be comprehensive by measuring broad factors assumed to be widely influential on employee perceptions of the quality of conditions at work, and overlap to a large degree with each other. Since the monumental influence of the Job strain model has resulted in it dominating the research concerned with musculoskeletal health outcomes, the “current state of knowledge” that is summarized in systematic reviews mainly pertains to this model.

Traditionally, attempts at explaining the impact of work on musculoskeletal pain have concentrated on the physical work situation and mechanical loads (Weiser, 2007; Bongers, 1993). Biomechanical risk factors such as e.g. repetition, force, and posture have been shown to play a part in the etiology and persistence of common musculoskeletal disorders (Faucett, 2005). However, these associations have not been as strong or specific as would be expected if biomechanical factors played the only part (Weiser, 2007). Although this could be partly due to not studying the correct mechanical exposures it has also catalyzed the notion that the etiology of work related pain is multifactorial and must encompass non-physical exposures (Huang, Feuerstein, & Sauter, 2002; Faucett, 2005; Bongers, 1993). During the past decades numerous scientific studies have shed light on the prospective association of psychological and social work factors with musculoskeletal complaints. Several systematic reviews (and systematic reviews *of* systematic reviews) have summarized the available scientific knowledge. Most of these have concluded that there is consistent evidence of a prospective relation between some “psychosocial work factors” and musculoskeletal pain complaints, particularly neck pain and back pain (Lang, Ochsmann, Kraus, & Lang, 2012; Bongers et al., 2006; Walker-Bone et al., 2003; Ariëns et al., 2001; Malchaire et al., 2001; da Costa & Vieira, 2010a; Hoogendoorn et al., 2000; Macfarlane et al., 2009; Hauke, Flintrop, Brun, & Rugulies, 2011).

Occupational psychological and social factors that have been found to be related to *neck pain* in many studies include lack of supervisory support (Malchaire et al., 2001; Ariëns et al., 2001; Walker-Bone et al., 2003), low social support (Ariëns et al., 2001; Bongers, Kremer, & ter Laak, 2002; van der Windt et al., 2000), low job control (Walker-Bone et al., 2003; Bongers et al., 2002; Bongers et al., 2006; van der Windt et al., 2000), high job strain, conflicts at work, and low job security (Ariëns et al., 2001). However, the factor most often reported as a significant risk factor of neck pain seems to be *job demands* (Bongers et al., 2002; Walker-Bone et al., 2003; Ariëns et al., 2001; Malchaire et al., 2001; van der Windt et al., 2000; da Costa & Vieira, 2010a).

For *back pain* systematic reviews have consistently designated *job dissatisfaction* a risk factor (Hoogendoorn et al., 2000; da Costa & Vieira, 2010b; Macfarlane et al., 2009; Linton, 2001; Lakke, Soer, Takken, & Reneman, 2009). Somewhat less consistently, high work demands, low job control, and low social support at work have by the same systematic reviews been cited as risk factors, associated with varying levels of evidence (Macfarlane et al., 2009; da Costa & Vieira, 2010b; Hoogendoorn et al., 2000; Linton, 2001). One systematic review of *prognostic* factors for low back pain supported the role of lacking colleague social support but not job dissatisfaction in predicting the *persistence* of pain (Hayden, Chou, Hogg-Johnson, & Bombardier, 2009). Another systematic review agreed that lack of social support should be considered a prognostic factor, but in contrast with other reviews claimed that it should *not* be considered a risk factor (Lakke et al., 2009). In general, consistency between studies seems fairly low. Hoogendorn et al. noted in their 2000 review that the conclusion regarding the level of evidence pertaining to workplace social support was sensitive to slight changes in the way they rated the methodological quality of the studies (Hoogendoorn et al., 2000). They also noted that job dissatisfaction was included in their review since it had been investigated in many of the studies but that it may not qualify as a "job characteristic" since it can be seen as a result of working conditions (Hoogendoorn et al., 2000).

Two more recent meta-analyses have come to similar conclusions regarding the role of psychological work factors and the development of musculoskeletal pain in several regions of the body. Lang and coworkers summarized studies that examined the lagged effect of psychological and social work factors on pain in different regions (Lang et al., 2012). They included two-wave panel studies that analyzed the effect of baseline exposure measures on the follow-up health outcome, controlling for the stability of the health outcome (i.e. adjusting for health at baseline). The possibility of publication bias was taken into account. Nine exposure categories were derived to describe exposures studied, namely *job demands*, *job control*, *job strain* (i.e. high demands and low control), *social support*, *supervisor support*, *coworker support*, *job satisfaction*, and *monotonous work*. They concluded that "most psychosocial stressors had small but significant lagged effects on the development of musculoskeletal problems" (Lang et al., 2012, p. 1163). Similarly, Hauke et al. included only longitudinal studies and concluded that "low social support, high job demands, low job control, low decision authority, low skill discretion, low job satisfaction, high job strain and psychological distress had statistically significant small to medium effects on risk of onset of MSDs" (Hauke et al., 2011, p. 253).

Thus, although the specific factors vary and the level of evidence has often been weak to moderate, most systematic reviews have reported some evidence of associations for some psychological and social work factors with musculoskeletal pains. As a counterweight to this, Hartvigsen and coworkers published a *critical* systematic review on low back pain (LBP) in 2004 in which they observed ”a striking lack of association between work related psychosocial factors on one side and LBP and consequences of LBP on the other" (Hartvigsen et al., 2004, p. 8). It seems that methodological variability in primary studies as well as in systematic reviews may contribute to confusion. Hartvigsen et al. suggested that the widespread use of non-validated instruments contributed to inconsistent findings across studies and noted that this can give rise to spurious positive findings in single studies (Hartvigsen et al., 2004). However, unreliable methodology could also contribute to negative findings in cases where true relationships exist. Additionally, even if inconsistent findings do indicate spuriousness, this could be a reflection of the limited range of factors that have been well documented. Many unknown factors could exist that are more relevant to the etiology, course, and severity of musculoskeletal pain than those that have been thoroughly investigated so far. Hence, the apposition of LBP on one side and "psychosocial factors" in general on the other side may not necessarily be warranted.

1.4.3.2. Headache

While much research has concentrated on musculoskeletal disorders, little research has been devoted to revealing occupational psychological factors that may influence headache. While headache is not usually classified as a musculoskeletal disorder, the tension-type is often attributed to muscular tension and studies have shown it to be strongly associated with musculoskeletal symptoms (see e. g. Hagen, Einarsen, Zwart, Svebak, & Bovim, 2002). Tension-type headache is the most common form of primary headache (i.e. headache that exists independently of other known medical conditions) (Fumal & Schoenen, 2008). However, although it is the most common headache it is not most commonly researched, possibly since it most often resolves without medical intervention beyond non-prescription painkillers (Fumal & Schoenen, 2008). Nevertheless, it remains common and may severely affect life quality and productivity on a large scale. The unspecific nature of tension-type headache suggests that its causes and precursors remain poorly understood. Fumal and Schoenen (2008) noted:

“Tension-type headache (TTH) is an ill-defined and heterogeneous syndrome, which is diagnosed mainly by the absence of features found in other headache types, such as migraine. TTH is, thus, a featureless headache that is characterised by nothing more than a pain in the head. The term tension-type was coined by the first Classification Committee of the International Headache Society to provide a new heading that underlines the uncertain pathogenesis but, nevertheless, indicates that some kind of mental or muscular tension might have a causative role” (Fumal & Schoenen, 2008, p. 70).

Cognitive factors such as self-efficacy and locus of control and emotional states such as depression, anxiety, and anger have been suggested to affect the severity and frequency of headaches (Nicholson, Houle, Rhudy, & Norton, 2007). However, very little research has investigated the relationship of psychological *work* exposures with headache and most of the existing studies have been cross-sectional. For instance, several Swedish cross-sectional studies have observed associations of headache with a ”mental work stress index” (Antonov & Isacson, 1997), dissatisfaction with work, worry about losing one’s job (Molarius, Tegelberg, & Öhrvik, 2008), and psychological demands and worry about work conditions (Aasa, Brulin, Ängquist, & Barnekow-Bergkvist, 2005). In a Taiwanese cross-sectional sample headache was associated with how often employees felt “very stressed” at work (Cheng, Guo, & Yeh, 2001). The few longitudinal studies that have been conducted have not reported unequivocal effects of psychological work factors on headache. One study observed an increased risk of incident migraine after two years for employees that reported an imbalance between invested effort and received reward, but effects of control, demands, and job strain were not detected (2007). Similarly, Kopec and Sayre reported no statistically significant association of job demands, control, support, job security, satisfaction, and “work stress” with subsequent physician-diagnosed migraine in employees drawn from a sample representative of the Canadian population (2004). It is worth noting that these studies pertained to migraine headache, which is a less prevalent and more specific condition than tension-type headache. On the other hand, a large French panel study found that the prevalence of general headache among employees of a large national gas and electricity company declined markedly after retirement (Sjösten et al., 2011). In other words, employment was associated with a higher prevalence of headache. Moreover, the group of employees that reported a combination of high job demands, high physical demands, and low job satisfaction reported the steepest decline in headache prevalence.

1.4.4. Some limitations of previous research

Much has been clarified by the substantial amount of research pertaining to psychological working conditions and musculoskeletal health. However, some common limitations of previous research should be discussed. The following is of course not an exhaustive list of limitations of previous research, but a discussion of some concerns that the current studies addressed.

1.4.4.1. Few factors have been studied

The Job strain model has been pivotal in demonstrating that psychological/social work factors contribute to risk of coronary heart disease (Kivimäki et al., 2006). In evaluating the history of research on the influence of “the work environment” on heart disease, Kasl noted in 1996 that "the research on work and coronary heart disease remained relatively haphazard until the focus provided in 1981 by the article on job strain" (Kasl, 1996, p. 47). Hence, Kasl commends the Job strain model for providing researchers with a focused aim and testable hypotheses. This research is still vital as confirmed by recent meta-analyses (Kivimaki et al., 2012). However, Kasl also advocated a broad approach that does not ignore the potential existence of other factors (Kasl, 1996). It is evident from systematic reviews, as cited above, that on the topic of musculoskeletal health “psychosocial factors” are still virtually equated with “Job strain”, “job satisfaction”, or “stress”. This may motivate general conclusions, based on available evidence, about what “psychosocial factors” can and cannot predict. While limited generalizability to the general population (of interest) is commonly disclosed in studies, it is far less common to extensively discuss the generalizability of studied factors to the theoretical *domain* of interest. It may nevertheless be important that research does not have the appearance of encompassing a whole domain ("the psychosocial work environment") when it deals with selected aspects of it ("some psychosocial factors"). In a 2010 systematic review of risk factors for work related musculoskeletal disorders Da Costa and Vieira noted that "the factors reported more frequently are not necessarily the ones with the highest level of evidence demonstrating their causal relationship with WMSD. Finally, the risk factors presenting a specific ''level of evidence'' associated with them, are not the only ones that should be considered; they are just the ones that have already been tested" (da Costa & Vieira, 2010a, p. 315). This highlights the importance of broadening the scope when examining psychological and social exposures at work. While the Job strain model has indeed revolutionized the research field by providing a frame within which it has been possible to attain more focused knowledge, its dominance of the research field may also have had a limiting influence.

Although a small number of factors have been subjects of investigation, some of these factors seem rather broad and unspecific. For instance, Karasek's Job demands dimension attempts to capture several potentially harmful influences (e.g. time pressure, role conflict, work amount) subsumed under the heading of presumably "demanding work" (Karasek et al., 1998). If the nature of these diverse influences is such that they have differential impacts on health complaints it may be unjustified to cluster them into one dimension. Distinctly different concepts may influence health differently, require different time periods, and be harmful under different conditions. One could for instance conjecture that a massive work load is harmful since it determines the degree to which an employee is exposed to unfavorable conditions that characterize the work situation. Hence, in isolation "quantitative" demands may be a neutral exposure that may determine the extent of exposure to, for instance, "conflicting demands", which may be harmful. In other words, work amount could be a catalyst of the adverse reaction to specific exposures. If the demand scale of the Job strain model is to be viewed as reflective of one underlying dimension, its psychometric properties seem questionable (Karasek et al., 1998). If, however, it is intended to be a *formative* index (that is, a collection of conceptually distinct factors that are not *necessarily* correlated although they may be grouped together on some basis, such as e.g. being work-related) internal consistency is of less concern, but the validity of comparing studies employing such a measure would only be high if the different factors comprised by the index had equivalent effects on the outcome. If time pressure and work amount, for instance, had different consequences for employee health the impact of identical scores on the scale would vary, depending on the composition of aspects that resulted in the observed score. Interpretations of results from previous research should take into account that they may represent a composite of factors that are differentially related to health. Consequently, interpreting inconsistent results as indication of absence of an impact of psychosocial work factors on health may be far too general.

Of course, the significance of introducing novel factors to the study of psychological work factors and pain complaints has not been completely ignored. The demand-control interaction hypothesis of Job strain was expanded to encompass social support as a “buffer”, i.e. a factor that can moderate the negative impact of high strain (Johnson & Hall, 1988). In principle, this does indeed represent a recognition of the need for inclusion of additional exposure factors in this type of research. Furthermore, recent expansions such as the Job Demands-Resources model (Demerouti, Bakker, Nachreiner, & Schaufeli, 2001) have pointed out the need for broadening the scope by including a wider variety of factors relevant to different types of jobs, and have also implied that there is a fundamental difference between the effects of different demands and resources. However, this acknowledgement that there may be a variety of less explored non-physical factors that influence health in different ways has not yet had a widespread impact on the research that examines musculoskeletal outcomes.

In conclusion, it may appear that an overreliance on general model-thinking has resulted in researchers concentrating their efforts on a narrow range of broadly defined factors. Work situations, which are complex and multi-faceted, may not be adequately captured by such general “grand theories”. The level of abstraction at which these models operate may not be well suited for detailed investigation since their general nature seems to encompass many different types of workplace exposures. Although the testing of different types of general theories has its place in the current research field there is a need for complementary approaches that emphasize more specific exposure concepts.

1.4.4.2. Classification of exposure

Dichotomization is common in studies employing the demand-control framework. For example, "strain" is often defined as the combination of "high" demands and "low" control. However, there is no given "natural cutoff" to distinguish "high" from "low" demands and control. Many studies use median splits to determine this distinction. However, splitting the sample in two may be problematic in several ways. It may lead to information loss and misclassification. Even if there were a natural categorical distinction between "high" and "low" scores there is a substantial risk of misclassification if the distribution of scores is not normal. Hypothetically, some employees may experience "high" exposure and the rest may experience "low" exposure, but that does not necessarily imply that it is theoretically meaningful to assume that fifty per cent of employees experience each condition. If most people in a sample experience low demands (if, for instance, studying an occupation characterized by lower demands than the general working population) a median split could result in inappropriate comparisons since the group classified with "high" demands would include many subjects with low demands. Instead of attempting to induce variability in the exposure measure the researcher might consider accepting the inherent homogeneity of the exposure in the sample. Furthermore, it is conceivable that there a third group exists that experiences "middle" demands and that this level of exposure is of relevance to the etiology of work-related health problems. If the relationship between "job demands" and "strain" is nonlinear so that "middle demands" do not produce "strain", but both high *and* low demands are taxing, the contrast of two groups characterized by presumably high and low demands would not be sufficiently informative.

Many studies have not focused on the demand-control interaction hypothesis (i.e. "strain"), but have rather tested the main effects of demands and control. Dichotomization is common in such studies too, as well as other forms of categorical classification of exposure such as tertile- or quartile splits. The motivation often seems to be (1) to facilitate interpretation by distinguishing between categorically "exposed" and "non-exposed" employees, and (2) that skewed distributions of work characteristics may affect statistical power due to few observations in the "extreme" categories. Percentile splits ensure that a certain percentage of employees will be classified into each category. Few employees may report high demands and even fewer may report a combination of high demands and low control. If the outcome under study is also categorical and exhibiting a relatively low prevalence statistical power may be diminished - very few employees will be classified as "exposed and ill". However, attempting to solve the problem of statistical power by regrouping subjects may introduce new and even more severe problems due to misclassification. Paradoxically, the result could be a loss of statistical power due to contrasting individuals that report similar exposure. As suggested above, another reason to categorize could be to explore the possibility of non-linear effects, e.g. that middle levels of exposure have the strongest effect. If so is the case, analyses assuming linearity would usually underestimate effects. However, because of the issues mentioned above, if one employs percentile splits it may be dubious to assume that the middle category reflects middle levels of exposure.

1.4.4.3. The modeling of exposure over time

The "stress" paradigm has been influential in research of psychosocial work factors and it is often hypothesized or assumed that "chronic" exposure to certain stimuli may induce adverse health effects over time (Faucett, 2005; Nixon, Mazzola, Bauer, Krueger, & Spector, 2011; Zapf, Dormann, & Frese, 1996). That is, responses that are adaptive in the short term may be harmful if they persist. Recent models utilized to explain effects of psychological work exposures, such as the allostatic load model (Mcewen & Stellar, 1993; Mcewen, 2000), maintain this notion. Nevertheless, there seems to have been little interest in investigating the effects of exposure over extended time periods, and surprisingly few longitudinal studies have utilized exposure information from multiple time points (Taris & Kompier, 2003; Davis & Heaney, 2000; Ganster & Rosen, 2013). Typically, the effect of baseline exposure measures is assessed to evaluate the prospective association of exposure with outcome. Among the few studies that serve as an example of the way in which repeated exposure information can be utilized was one four wave study that examined the effects of *stable* and *changing* demand-control "histories" on *sleep quality* and *fatigue* in Dutch employees (de Lange et al., 2009). Reduced sleep quality may lower pain thresholds (Moldofsky, 2001) and may thus be one mechanism by which work exposures contribute to pain. De Lange et al. observed that employees reporting prolonged high levels of job strain (i.e. high demands, low control) reported the poorest sleep quality and the most fatigue.

Also, this group reported the steepest increase in the severity of these complaints. Stable low strain, on the other hand, was associated with the lowest levels of these complaints as well as no increase over time. Similarly, de Lange et al. (2002) observed effects of stable strain on depression and job satisfaction (de Lange, Taris, Kompier, Houtman, & Bongers, 2002). These studies demonstrate the desirability of future studies to explicitly model exposure as a function of time. However, the problem of classification of different levels of exposure remains problematic when no "natural" cutoff criteria exist.

1.4.4.4. Non-validated self-report instruments

The use of self-report instruments is convenient in many research contexts. First of all, self-administered questionnaires represent a cost-effective way to attain extensive information about many variables from many subjects. Secondly, employees are natural experts on working conditions, particularly when the interest is in the perceived, subjective environment. Moreover, when information is required from many subjects the opportunity to sample at frequent time points is usually limited, meaning that a subject's appraisal of the general working conditions is more informative than "objective" information about specific days or hours each time which may miss important work events. Finally, when the outcome measure is a subjective health complaint or regards the subjective symptoms of a medical condition, self report is the only way to approximate a measurement. However, subjective self-report is often considered vulnerable to bias. Sometimes this criticism seems to be aimed at the use of self-report *per se,* when the attached argument seems more relevant with regard to the way in which such data were collected and interpreted. Many studies of the past may seem to have ignored the significance of employing thoughtfully constructed self-report instruments for the measurement of psychological work exposures. Davis and Heaney (2000) reported in a systematic review of psychosocial work factors and low back pain that only one third of the studies they reviewed employed well-validated multiple-item measures. Four years later, Hartvigsen and coworkers (2004) conducted a systematic critical review of the same topic and they also noted the common use of non-standardized, non-validated "ad hoc" instruments for measuring exposure. Some criticisms of the notion that psychological work factors may influence health seem to fail to acknowledge the difference between "bad and good" ways of implementing self-report methodology.

A common assumption seems to be that self-reported "psychosocial exposure" is necessarily measured by heavily value- or affect-laden items. Macleod and Smith stated that "social disadvantage is associated both with poorer physical health and with heightened exposure to various psychosocial factors – all with a negative social connotation" (Macleod & Smith, 2003, p. 566). By this they challenged the notion that "adverse psychosocial exposure" ("misery", as they dubbed it) can cause physical disease. This argument is based on the assumption that measures of exposures convey explicitly negative content. This may, however, be truer for some concepts than others. When asking respondents about conflict or bullying, for instance, the events in question are to most respondents inherently negative. Similarly, it seems intuitively plausible that "job satisfaction" and "job stress" could reflect more general constructs of "life satisfaction" and "life stress". These concepts may indeed be associated with causes of ill health that have little to do with psychological working conditions. "Satisfaction" and "stress" quite obviously reflect degrees of negative/positive emotions that may be partially caused by general "misery" in life. If a "negative" work situation merely acts as a proxy for a "negative" life situation, modifying work factors e.g. to increase job satisfaction will not be particularly beneficial to employee health.

However, the degree to which work factors are *inherently* negative/positive (and thereby reflect "misery" and poor living conditions) may vary. Reports of global "satisfaction" at work may be more likely to be influenced by negative non-work life circumstances than, for instance, items about how frequently a supervisor encourages participation in important decisions or how frequently one has received incompatible requests from multiple persons. It is of course still possible that employees evaluate the content of questionnaire items and decide to answer in a way that overstates the problem, but this seems less likely to be a major problem, especially when measures are based on multiple items and respondents are faced with numerous topics and factors. Hence, measures of psychological exposures should strive to be as *neutral and specific* as the concepts allow, encouraging respondents to actively evaluate specific aspects of their job rather than conveying their general emotions about it. While it may be inherently difficult to author neutral questions about working conditions that are free from negative/positive connotations, psychometrically validated questionnaires should address such issues and minimize such connotations. The use of single item-measures of global appraisal of "satisfaction", "stress" or "too much to do" seem much more vulnerable to the influence of negative thinking. Thus, since self-report is necessary in the study of psychological constructs focus should not be on avoiding it, but rather on applying and interpreting it appropriately.

Watson and Pennebaker (1989) were influential in raising a general concern about how "*reporting biases"* related to personality dispositions may confound associations of self-reported psychological factors and self-reported health. They analyzed extensive data on trait negative affectivity (NA) and different indicators of health and concluded that "NA can be expected to act as a general nuisance factor in health research, one that taps psychologically important but organically spurious variance in physical symptom measures. We must remain skeptical of any study that uses a health complaint scale as its criterion for health and that includes, as a psychological predictor, a measure with a subjective distress component. The danger always exists that such a predictor is assessing – either partly or completely – variance that is uninteresting from an objective health standpoint (however interesting it may be psychologically)" (p. 248-49). It should be stressed, however, that this pertains to exposure *measures with a distress component* and symptom report as an indicator of *organic disease.* In the same study, Watson and Pennebaker *supported* the specific notion that anxious individuals may be more sensitive to pain. Hence, their concerns are most pronounced when a clear theoretical distinction between "subjective" and "objective" health can be asserted. If the aim is to estimate "objective" health (e.g. coronary heart disease) by a measure of "subjective" health (e.g. angina pectoris) validity will be influenced by "nuisance"-variables such as NA. Concerns about self-report data often regard studies that obtain diagnosis of organic disease by subjective symptom report. For instance, Macleod and coworkers warned that "if people who perceive and report their life as most stressful also over-report symptoms of cardiovascular disease then an artefactual association between stress and heart disease will result" (Macleod et al., 2002, p. 76). Symptoms that are consistent with cardiovascular disease may be experienced in absence of such disease. Thus, "over-report" of symptoms may denote two conditions: (1) Symptoms have been experienced, but are not caused by heart disease, or (2) symptoms were reported but did not occur. Even accurately reported non-specific chest pain resulting from "stress" would unquestionably constitute a bias in cardiovascular disease research. However, this is not because the self-report is intrinsically non-valid, but rather because it is a non-valid diagnostic criterion of coronary heart disease. If the research interest is *chest pain* as a health problem bias may be present under condition (2), where the subject inflates the report of previous symptoms. However, this is inherently difficult to determine as pain is by definition a subjective symptom. Thus, it may be important to hold in awareness the distinction between “subjective” and “objective” health when discussing the validity of self-report. When evaluating claims that evidence is lacking of psychological/social factors causing “physical disease”, it should be kept in mind that many of those who experience disabling musculoskeletal pain exhibit no obvious physical manifestation of “disease”.

Thus, sometimes one researcher may judge as “bias” or “contamination” what another researcher considers “substantive information”. However, even if subjective data may reflect substantive information that is sometimes labeled as “bias”, the possibility that self-report may induce certain types of systematic error cannot be excluded. If the influence of reporting behavior influences exposure and outcome report in a similar way they may correlate in spite of *no causal connection* other than both being a common consequence of the method (i.e. *common method bias* (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003)). Predispositions such as NA may cause individuals to report worse working conditions as well as worse health so that a spurious association results. This is not necessarily a question of “measurement error” since both measures may accurately reflect the individual’s experience. Rather, it is a question of uncontrolled third factors that cause both exposure and outcome. This is the case if subjective work factors and health are both influenced by personality dispositions. Nevertheless, it is also possible that correlated measurement errors can cause bias. Exposure and outcome measures may unintentionally overlap with concepts that are not the subject of investigation (for instance by measuring “negative feelings”, which may be a component of both ill health and adverse working conditions). Therefore, careful considerations of *what* is being measured as well as *how* it is being measured are necessary and may not have been adequately dealt with in many previous studies.

Although little empirical evidence suggests that common method bias represents a considerable problem in practice many researchers choose to adjust for individual dispositions associated with negative affect (Spector, 2006; Spector, Fox, & Van Katwyk, 1999). However, this strategy ignores the possible *substantive* role of negative affect and affectivity and may induce bias instead of removing it (Spector, Zapf, Chen, & Frese, 2000). Personality may play a substantive role in explaining who are exposed to and experience adverse working conditions as well as who are more vulnerable to the effect of potentially harmful conditions. Although some individuals may be more prone to severe reactions to exposure due to "overly" negative interpretations of their social environment this does not in itself negate the existence of the exposures (in much the same way, if physical fitness determines the effect of heavy loads it does not mean that the loads are irrelevant). But perhaps most importantly, if psychological conditions at work influence mood and affect, and thereby modulate pain, adjustment for negative affect(ivity) would be highly inappropriate. As previously discussed, affect is a putative *mediator* or *moderator* at least as much as a potential *nuisance*.

1.4.4.5. Predicting the "incidence" of pain

In reviewing "the influence of the work environment on cardiovascular health" in 1996 Kasl stated that "a major issue is how to understand the possible ways in which psychosocial variables can impact the health-to-disease transitions" (Kasl, 1996, p. 44). Reflected in this is perhaps one crucial conceptual distinction between heart disease and musculoskeletal health complaints; cardiovascular health may be more amenable to a "health vs. disease-distinction". Ultimately, the end points of cardiovascular disease are unequivocal. For musculoskeletal health complaints there is typically no definitive objective definition of disease and the only manifestation of illness is often the subjective state of pain. Much of the evidence of the implication of psychological work factors in musculoskeletal pain is derived from studies that predict the incidence of pain, and the term "risk factor" is often employed to connote a factor that increases the risk of transitioning from one state of health to another. Thus, many studies investigate the impact of working conditions on the occurrence of new onset pain at a follow-up among a group of subjects that reported no pain at baseline.

The concept of pain incidence, or the strategy of measuring it by a simple two-wave design, may be problematic since pain exhibits substantial variation over time (Steingrimsdottir, Vollestad, Roe, & Knardahl, 2004). This could attenuate true associations by introducing random misclassification. While it is fair to claim that pain is either present or not at any given time point, it seems more questionable to assume that a single pain report at a second measurement occasion reflects “onset of pain” as long as it is unknown whether this pain is enduring or occasional. Furthermore, even if one could assume that those reporting no pain at wave 1 of a study but do report pain at wave 2 actually reflect a group of individuals with a newly emerged pain problem, it is not safe to assume that the *onset* of pain is the only aspect that can be influenced by putative causal precursors. Including the range of pain from no pain to severe pain may be more informative, as it is possible that factors modulate the degree and/or duration of pain rather than determining its existence. Thus, questions regarding the possible impact of psychological work factors on pain should more actively consider the non-dichotomous nature of pain. This would elucidate the phenomenon more thoroughly and may acquire necessary sensitivity to detect possible relationships. Statistical power may be low when predicting a dichotomous outcome. If the relationship of psychological factors with the transition from no pain to pain is the same as for moderate pain to severe pain dichotomization may represent unnecessary information loss. Systematic reviews most often sum up evidence pertaining to the occurrence of pain (see e.g. Bongers et al., 2006; Hauke et al., 2011; Hartvigsen et al., 2004; Hoogendoorn et al., 2000) and if the typical study designs are not sensitive enough to detect the putative effects of psychological working conditions on the incidence of pain, this may suggest one reason for inconclusive results of previous research.

1.4.5. Pathways: How can psychological and social working conditions influence pain?

The putative causal relationship between psychological and social work factors and pain complaints is most likely of great complexity. The multifactoriality of pain suggests that no single work factor or domain of exposures (e.g. psychological or mechanical factors) is sufficient to explain work related pain complaints. Furthermore, some psychological and mechanical factors may share pathogenic aspects and interact in numerous ways while other psychological and mechanical factors may exhibit distinctly separate paths to pain or ill health. Also, different psychological factors may exhibit different impacts on different health complaints, implying for instance different time courses or exposure dose requirements. Moreover, different psychological factors may influence different health complaints by similar mechanisms while other factors may influence the same health complaint differently by different mechanisms. Thus, it is possible that no single pathogenesis can be specified since "psychological work factors" is not one type of exposure, but rather comprises an array of processes that may exhibit differential impacts on health. Little is known with certainty about the mechanisms of work-related pain. However, many suggestions have been forwarded, and a general overview of these will be given in the following. The suggested ways in which exposure may influence health are rarely mutually exclusive and may interact and reinforce each other, so the following mechanisms are not necessarily competing theories. In some cases the different perspectives may even represent different levels at which the same mechanism is viewed. For instance, neuroendocrine factors are intimately intertwined with behavioral, cognitive, and emotional factors.

1.4.5.1. Neuroendocrine factors

As demonstrated by Cannon and Selye many years ago, the neuroendocrine systems enable the adaptation to environmental challenges. Psychological responses to perceived challenges are accompanied by a number of physiological activation patterns that are adaptive in the short term but that have been hypothesized to be harmful if sustained. Two systems in particular have been implicated in the response to psychologically demands, namely the HPA (Hypothalamic-pituitary-adrenocortical) -axis and the SAM (sympathetic-adrenal medullary) system (Nixon et al., 2011; Lundberg, 2005; Cohen, Kessler, & Gordon, 1995).

Activation of the SAM system is what produces the co called "fight-or-flight"-response to acute stressors. The hypothalamus initiates sympathetic arousal, causing the adrenal medulla to secrete the catecholamines epinephrine and norepinephrine. These hormones cause increased pulse rate, sweating, increased blood pressure, muscle tension, and other physiological responses associated with acute arousal that are helpful in preparing the individual for physical challenge (Lundberg, 1999). Since challenging job tasks frequently do not require much physical effort, many employees experience this mainly when faced with mental demands. Excessive activation of this system is thought to contribute to atherosclerosis and an increased tendency for the blood to clot, as well as chronic physical symptoms such as headaches, back pain, and other musculoskeletal pains (Nixon et al., 2011). In addition to causing exaggerated hormone release psychological challenge may interfere with the recovery process that is necessary after this has occurred (Lundberg, 2003). Many physiological processes associated with the adaptation to challenge are catabolic and require compensatory anabolic processes to ensure healing and recovery. If problems at work cause disrupted sleep or unhealthy habits recovery may be affected.

The HPA axis is also activated when the individual perceives something as a challenge. The hypothalamus releases corticotropin-releasing hormone (CRH) into the hypothalamic-pituitary portal system. This induces secretion of (among other) adrenocorticotropic hormone (ACTH) from the pituitary gland. ACTH stimulates the adrenal cortex to release corticosteroids (e.g. cortisol) that enable immediate action by increasing blood sugar, suppressing the immune system, and facilitating metabolism of fat and protein. Metabolism is switched from anabolic to catabolic. The corticosteroids also inhibit the further release of CRH, and this feedback effect prevents prolonged activation of the HPA system and thus helps the return to the state that was prior to exposure to the challenging event. Chronic activation of the HPA system is thought to increase risk of cardiovascular disease, impaired immune functioning, depression, and cognitive disturbances (Lundberg, 1999).

Thus, central features of the endocrine system promote behaviors that throughout evolutionary history have been useful in dealing with demands. Typically, such challenges entail time-limited situations and resolution will signal the onset of anabolic processes. However, sustained exposure to adversity may prevent this resolution and may hinder anabolic restoration and thus put tissues at risk (Theorell & Hasselhorn, 2002). One model that describes the potentially pathogenic consequences of hormonal responses to psychological challenge is the *allostatic load* model (Mcewen, 2000). Allostasis means “maintaining stability through change” and describes the adaptive response to acute challenge which is characterized by temporary alterations of hormonal activity followed by recovery. “Allostatic load” occurs when hormonal response patterns depart from this (and the normal, stable patterns of hormonal secretion that are maintained in diurnal rhythms). Thus, four conditions are described as allostatic load (Mcewen, 2000): (1) Frequent activation by multiple novel stressors that each time elicit a “new” adaptation response, (2) failure to adapt to a stimulus, resulting in repeated activation in response to a non-novel stressor, (3) prolongation of the response with a resulting lack of recovery, and (4) inadequate response from one endocrine system that causes compensatory hyperactivity in other systems normally regulated by it. These hypotheses emphasize the time dimension and provide a mechanism by which even relatively minor events (compared to psychological trauma) can disrupt health. It also takes into account individual differences in the adaption to environmental challenges. For instance, Kirschbaum and coworkers investigated individual differences in the habituation to a challenge involving public speaking (Kirschbaum et al., 1995). While some subjects exhibited significant decreases in cortisol secretion after having to face this challenge repeatedly, one subgroup failed to adapt and exhibited similar elevated cortisol responses every time they were confronted with the same challenge. This suggests one way in which personal characteristics may play a role in determining the physiological impact of a clearly external demand such as public speaking.

The way in which hormonal responses to mental demands could affect physical health is not clarified. For instance, the role of the HPA in modulating the expression of inflammatory symptoms may not be in the level of hormones per se, but rather in the way in which target tissues respond to e.g. cortisol after repeated exposure to it. Consistent with this notion, a recent experimental study demonstrated that subjects who had experienced "stressful life events" during the last year were more likely to exhibit glucocorticoid receptor resistance (GCR) (Cohen et al., 2012), implying decreased receptivity to cortisol and its anti-inflammatory properties. Furthermore, these subjects with CGR were more likely than others to develop a cold after being experimentally exposed to a rhinovirus. Moreover, CGR predicted the amount of proinflammatory cytokines produced in response to the cold. Thus, exposure to severe prolonged adversity may affect the inflammatory response by blocking the anti-inflammatory effect of cortisol.

1.4.5.2. Muscle activity and mechanical load

Mentally challenging tasks or prolonged periods of mental exertion may influence the way in which employees execute work tasks. Thus, a behavioral pathway to muscle pain may go through established biomechanical risk factors. For instance, working with arms raised above shoulder level is a risk factor for neck pain (Hales, 1996; Viikari-Juntura et al., 2001). Individuals striving to satisfy job demands under time constraints may take fewer and shorter breaks from work involving such postures, which may contribute to pain (Strøm, Røe, & Knardahl, 2009). In other words, psychological factors may precipitate adverse biomechanical exposure. However, although risk attributed to mechanical factors may be more pronounced in occupations involving manual materials handling, for instance, the role of muscle activity in sedentary work is less obvious. In office work biomechanical loads are generally assumed to be low. Since the study of Travell and coworkers (1942) many hypotheses of work-related muscle pain have focused on muscle tension as a possible explanatory factor that could account for the prevalence of pain in such occupations (note that muscle tension is one result of the physiological processes initiated by the neuroendocrine systems described above). This implies that peripheral nociception could occur as a consequence of muscle contraction resulting from psychological challenge at work (Knardahl, 2002). Cognitive tasks have been shown to increase task-irrelevant muscle activity in different regions of the body (Wærsted & Westgaard, 1996). Furthermore, being exposed to cognitive demands in combination with physical load demands seems to increase muscle activity more than either demand alone (Lundberg et al., 1994).

Although increased muscle activity may occur during mental and cognitive demands little is known about how this would activate nociceptors. However, several theories have been proposed. Many theories have explained musculoskeletal pain as resulting from insufficient blood circulation due to intramuscular pressure during contraction (Knardahl, 2005). Resulting hypoxia, ischemia or metabolic products may activate nociception. However, such mechanisms remain most relevant for contractions of a magnitude sufficient to block blood supply. Although such demands are increasingly rare in modernized work life the problem of musculoskeletal pain does not decrease accordingly. One attempt to explain pain as a result of low-level enduring muscle contraction has been the “Cinderella hypothesis” (Hägg, 1991). “Cinderella fibers” are muscle fibers that are activated at low levels of contraction. Hence, they are often active, perhaps much of the time resulting from cognitive and emotional demands, and their sustained activity has been proposed to cause cell injury. However, how such cell injury would activate nociceptors remains unclear and overall it appears that the correlation between reports of pain and subjective tension is stronger than the correlation of pain with objectively measured muscle activity (Knardahl, 2005). It could be that muscle tension is a consequence of pain, suggesting a reverse causality hypothesis called the “pain adaptation model” (Lund, Donga, Widmer, & Stohler, 1991). Based on the unspecific association of muscle-cell activation with pain and the location of nociceptors close to the vasculature of the muscles, Knardahl (2002) proposed the “blood vessel-nociceptor interaction hypothesis” (Knardahl, 2002). This hypothesis suggests that "pain originates from the vessel-nerve interactions of the connective tissue of the muscle, rather than from energy crisis of the muscle cells" (Knardahl, 2002, p. 68). This may encompass a variety of pain-generating mechanisms such as e.g. vasodilatation stretching the vessel wall, release of algogenic substances from nerves and vessels (e.g. prostaglandins), and inflammatory processes that sensitize nociceptors. Experimental evidence has demonstrated that intramuscular trapezius blood flux but not muscle activity correlated with pain during simulated office work under time pressure (Strøm et al., 2009).

1.4.5.3. Vulnerability to other exposures

The impact of non-physical work factors on physical health may in some instances be by determining the sensitivity to other exposures. Mechanical loads that would normally be tolerable may be perceived as intolerably painful due to a lowered pain threshold. Pain thresholds have been suggested to be highly susceptible to modification by environmental factors (MacGregor, Griffiths, Baker, & Spector, 1997). Experimental studies have indicated that high psychological demands may increase pain thresholds while low control may reduce them (Theorell, Nordemar, & Michelsen, 1993). In one recent experimental study unpredictable administration of a noxious stimulus was associated with more intense pain for individuals with higher scores on a scale of helplessness, and these individuals exhibited a more pronounced cortisol response (Muller, 2011). This is suggestive of the role of certain psychological factors in modulating pain that originates elsewhere. Poor sleep and depression have been shown to be independently associated with lowered pain threshold in a population based study in the United Kingdom (Chiu et al., 2005). This may suggest two possible pathways by which psychological work exposures modify the experience of potentially painful stimuli.

1.4.5.4. Cognition and emotion

Biopsychosocial perspectives emphasize the interaction of thinking, emotion, behavior, and the body in ways that may ultimately reinforce or alleviate pain. For instance, the *fear-avoidance model* posits that negative appraisals of bodily sensations and catastrophic interpretations (e.g. the persuasion that pain indicates serious pathology) may influence pain severity and duration (Lethem, Slade, Troup, & Bentley, 1983). Thus, fear of pain may endorse maladaptive pain-related coping strategies such as avoiding activity, leading to a disuse syndrome and further exacerbation of the health problem. Cognitive behavioral therapies have been shown to be efficacious in reducing pain intensity in chronic low back pain patients (Hoffman, Papas, Chatkoff, & Kerns, 2007).

Hence, ways of thinking about the environment may play an important part in determining health and could be involved in the pathway from work to health. For instance, adverse working conditions may induce depressed mood and/or anxious thinking that favors pessimistic attributions. This could result in decreased coping abilities that increase the likelihood of pain occurring or becoming unmanageable. Studies have shown that future episodes of low back pain, chest pain, headaches, and musculoskeletal complaints were more likely in subjects suffering from depression (Bair et al., 2003). Perhaps more relevant to acute pain or the severity of chronic pain, a considerable body of research has demonstrated the power of *nocebo* responses in modulating pain (Benedetti, Lanotte, Lopiano, & Colloca, 2007). One factor that may be involved in nocebo is anticipatory anxiety, i.e. the fearful expectation of an adverse event. Studies have demonstrated that expectations can influence spinal cord pain processing (Matre, Casey, & Knardahl, 2006) and induced mood has been shown to activate descending pathways that may inhibit or facilitate nociceptive transmission (Wiech & Tracey, 2009). As pain is modifiable by attention (Legrain et al., 2012) it may be reinforced if attentional processes are selectively oriented towards potentially threatening stimuli. Attention bias to threat and negative interpretive bias may manifest in interpretations of uncomfortable, yet benign bodily sensations as “symptoms”. Keogh and Cochrane demonstrated that subjects exhibiting high anxiety sensitivity (i.e. a tendency to be fearful of anxiety-related sensations) reported more sensory and affective pain during a cold pressor task, and that this relationship was mediated by a tendency to misinterpret bodily sensations as threatening (Keogh & Cochrane, 2002). Individuals who appraise somatic sensations by catastrophic thinking may intensify the sensation and exacerbate the pain. Also, a recent study showed that experimentally induced optimistic mood predicted lower pain intensity during a cold pressor task (Hanssen, Peters, Vlaeyen, Meevissen, & Vancleef, 2013).

1.5. Work exposures studied for the current thesis

The psychological and social exposure factors included in the current studies were assessed by The General Questionnaire for Psychological and Social Factors at Work (QPS_{Nordic}) (Dallner et al., 2000). The QPS_{Nordic} was originally developed based on a recognition of the need for a comprehensive instrument that compiles a large number of factors that have been central in occupational health psychology. Rather than constructing an instrument intended to test one particular general theory, the QPS_{Nordic} was intended as a comprehensive "check-list" of specific psychological and social factors essential to working conditions. Hence, the development of the QPS_{Nordic} was initiated by the Nordic Council of Ministers as part of an initiative aiming to improve the scientific quality of the study of psychological and social work factors as well as the practice of organizational improvement efforts (Lindström et al., 1997). Three specific purposes were stated: (1) To enable organizational development efforts, (2) to facilitate research on work and health, and (3) to document working conditions and changes over time (Lindström et al., 1997). In order to accommodate these aims a review of existing Nordic measurement instruments was conducted to define the content domain to be covered. This review uncovered that few existing instruments had been systematically validated. The following themes were identified and chosen for inclusion in the questionnaire:

a) communication in the organization
b) job demands, including role expectations
c) control at work
d) predictability at work
e) mastery of work
f) leadership

g) social support
h) bullying and harassment at work
i) organizational culture
j) working groups and teams
k) organizational commitment
l) work motives
m) work centrality
n) interaction between work and private life.

Studies I-III in the current thesis utilized a fairly wide selection of factors from the QPS_{Nordic} in order to gain a general overview of the explanatory value of different factors for different health complaints. However, for practical reasons it was not possible to include all of the abovementioned themes and the tentative nature of the selection procedure should be recognized. The scope was comprehensive but not exhaustive. By necessity the selection of factors was not "systematically" based on their health-relevance since the relationship between these exposure domains and different health complaints is largely unknown. The aim was to discover such relationships and thus the explorative nature of the project to a large extent precluded prior knowledge to determine the selection of factors. The following factors from the QPS_{Nordic} were studied in the current works:

Scale	Brief description
Quantitative demands	time pressure and amount of work
Decision demands	demands for attention and making quick and complex decision
Decision control	influence on decisions pertaining to one's work tasks, choice of co-workers, clients
Control over work intensity	influence on pacing, breaks, and time
Positive challenge	usefulness of skills, meaningfulness of work, and work is challenging in a positive way

Support from immediate superior	instrumental, emotional, and evaluation support
Role conflict	conflicts between demands and resources, conflicting requests
Role clarity	clarity of objectives and expectations at work
Empowering leadership	encouragement to participate in important decisions, to express different opinions, and develop one's skills
Fair leadership	whether the immediate superior distributes work fairly and treats workers equally
Predictability during the next month	predictability pertaining to tasks, co-workers, and superiors
Commitment to organization	positive feelings about and alignment of values with the organization
Social climate	whether the social climate is encouraging/supportive, distrustful/suspicious, relaxed/comfortable

In the following a brief presentation of the topics and concepts covered by the current thesis is given. This overview encompasses the abovementioned factors from the QPS_{Nordic} as well as global *job satisfaction* and *mechanical* factors.

1.5.1. Job demands

"Demands" is a central concept in occupational health research. In 1979 Karasek defined job demands as "stress sources (stressors), such as work load demands, present in the work environment" (Karasek, 1979, p. 287). An alternative formulation is "all those occurrences, circumstances, and conditions in the workplace that put pressure on the individual" (Dallner, 1997). The designation of specific types of work events as psychologically demanding is difficult because of the role of subjectivity. Individual subjective evaluation may determine whether or not a work factor "puts pressure on the individual". As previously mentioned the distinction between "subjective" and "objective" work factors has been debated, often with emphasis on measurement methods rather than conceptual definition and ontology (see e.g. Semmer, Zapf, & Greif, 1996;

Kompier, 2005). “Objective” demands would refer to a uniform class of demands that could be defined independently of individual employee interpretation of conditions at hand. On the other hand, “subjective” demands would encompass the appraisal of the demands by the individual and the meaning attributed to them. Learning and habituation resulting from prior experience may determine the extent to which a person experiences a demand as “demanding”. “Objective” demands may be easier to modify since they are defined in terms of external, structural conditions. However, certain types of psychological demands may not be amenable to objective measurement since they refer to the *meaning* of events to the individual employee. Demands are often measured by self-report instruments that refer to quantitative aspects of demands that may be seen as objective in principle, such as time pressure or work amount (Karasek et al., 1998). Such factors are, however, dependent on the subject’s appraisal of the demands and the individual capacity to meet them.

The QPS_{Nordic} separates aspects of the job demands concept and defines several types of subjectively appraised demands. The ones that were included in the current studies are *quantitative demands* (amount of work, time pressure) and *decision demands* (demands for attention and making quick and complex decisions). As reviewed above, the broad concept of job demands (which also includes *role conflict*, which will be presented in a later paragraph) has frequently been studied as a risk factor for pain complaints. More specific aspects of demands have also been studied, although less extensively. For instance, *time pressure* has been cross-sectionally associated with tension type headache in a Danish population study in women, but not men, of 25-64 years (Rasmussen, 1992). A systematic review including both prospective and cross-sectional studies concluded that time pressure was related to musculoskeletal symptoms (Bongers, 1993). However, a study of employees in the Dutch manufacturing industry reported no cross-sectional association of time pressure with self-reported musculoskeletal health complaints (Roelen, Schreuder, Koopmans, & Groothoff, 2008). Time pressure, but not mouse/keyboard work or ergonomic conditions, affected the prognosis of arm pain in a 1-year follow-up study of 6943 computer workers (Lassen, Mikkelsen, Kryger, & Andersen, 2005). The risk of chronic low back pain after one year was observed to be elevated among male German construction workers under time pressure (Latza, Pfahlberg, & Gefeller, 2002). A study of 157 nursing aides indicated that time pressure was associated with onset of low back pain on the same day as exposure occurred (Gonge, Jensen, & Bonde, 2001). *Long work hours* have been associated with health factors such as anxiety and depression (Kleppa, Sanne, & Tell, 2008; Shields, 1999), unhealthy weight gain, smoking, and drinking (Shields, 1999). Moreover, a recent meta-analysis concluded that working long hours was associated with a 40% excess risk of coronary heart disease (Virtanen et al., 2012). A recent study investigated an index of task demands reflecting among other things intellectually demanding work and complex tasks (corresponding with *"decision demands"*) and found that such demands were related to elevation of "stress" levels, measured as an index comprising health complaints such as headaches and mental agitation (Herrero, Saldana, Rodriguez, & Ritzel, 2012).

1.5.2. Job control

Control is often conceptualized as autonomy and the opportunity to participate in and execute planning and decision-making (Dallner et al., 2000). The Job strain model defines job control (also called decision latitude) as a combination of *skill discretion* and *decision authority* (Karasek et al., 1998). Skill discretion implies the execution of skill and ability, and is operationalized by items such as ""my job requires a high level of skill" and "my job requires that I learn new things" (Karasek et al., 1998). The requirement to execute skill may be seen as a challenge/demand as well as a resource, and is perhaps reflected by the QPS_{Nordic} scale of *positive challenge* (e.g. "are your skills and knowledge useful in your work?", "is your work challenging in a positive way") (Dallner et al., 2000), which was included in the current studies. Decision authority pertains to the general freedom to make decisions that affect aspects of one's work situation. In the current thesis *decision control* covers the degree to which employees have control over decision making that influences the way in which work is carried out (i.e. methods chosen, when to contact clients, and whom to collaborate with). Also, *control over work intensity* was studied. This concerns the opportunity to regulate pacing, breaks, and working hours.

Much research based on the job strain model has shown job control to be related to health. However, conceptualizations have varied somewhat. In their recent systematic review and meta-analysis of studies investigating the onset of musculoskeletal complaints, Hauke et al. reported that 23 studies investigated "control", 22 investigated "skill discretion", and 18 investigated "decision authority" (Hauke et al., 2011). Low "control" was a risk factor for both neck pain and low back pain. However, the effects of the separate aspects of "control" seemed to differ depending on the pain region – for *neck pain*, low "decision authority" exhibited a fairly strong risk (odds ratio 1.70) and "skill discretion" a non-significant effect close to no association (odds ratio 0.95). On the other hand, for *low back pain* "decision authority" exhibited a not statistically significant effect (odds ratio 1.19) while "skill discretion" was a statistically significant risk factor (odds ratio 1.40). The decision latitude concept has been criticized for comprising a mixture of different factors that may be differentially related to different outcomes (see e.g. Kristensen, 1995).

1.5.3. Support

Many studies of work and health have studied some form of social support. This is mainly due to the claim that the adverse impact of job strain can be buffered by the presence of support from social networks surrounding the worker (Theorell & Karasek, 1996). The presence of "strain" in social isolation, called iso-strain, is proposed to be the worst condition, and has been associated with adverse health (Theorell & Karasek, 1996). At work social support can be received from multiple sources and in multiple ways. For instance, distinctions can be made between *instrumental* and *emotional* support or support from *colleagues* vs. *superiors*. The current studies included *support from the immediate superior,* encompassing instrumental, emotional, and evaluation support.

Results from studies examining effects of social support on musculoskeletal health have exhibited somewhat inconsistent results. As is reviewed above, the protective effect for musculoskeletal complaints has been supported in many studies, but does not seem very specific. Although the "buffer" hypothesis of social support implies it to be a moderator of other factors at work most studies have examined the direct effect. However, some efforts have been made to examine ways in which support may modify the impact of other factors. For instance, studies have indicated that increased support can *increase* distress in work units with a high number of stressors present whereas it can *decrease* distress in units with lower levels of stressors (Buunk, Janssen, & Vanyeperen, 1989). One study also found that support from superiors and colleagues protected against low back pain, but that support from the colleague one *feels closest to* produced detrimental effects (Elfering, Semmer, Schade, Grund, & Boos, 2002). This seems to be in line with studies indicating that the support and empathy provided by significant others can reinforce maladaptive pain behaviors and contribute to exacerbation of pain conditions (McClelland & McCubbin, 2008; Sambo, Howard, Kopelman, Williams, & Fotopoulou, 2010). One could speculate that emotional support may not reduce distress if coupled with a lack of instrumental support, as it may elaborate but not solve a problem, which could induce rumination and catastrophizing that ultimately exacerbate the condition. Although there are many sources and kinds of support, systematic reviews often discuss "support" as one dimension, including e.g. general workplace social support and supervisor support in overall judgments of whether support is influential for pain complaints (see e.g. Hartvigsen et al., 2004; Hauke et al., 2011). In the current thesis support from within the work unit is encompassed by the *social climate* factor (e.g. "is the climate in your work unit encouraging and supportive?"), whereas support from management is encompassed by the factor of *support from immediate superior* (e.g. "if needed, can you get support and help with your work from your superior?").

1.5.4. Role expectations

Imperatives attached to the work role are necessary to define appropriate behavior and provide the individual with a set of criteria necessary to define achievement. However, the breakdown of communication of these expectations may result in equally adverse consequences. Research regarding role expectations usually refers to three distinct concepts, namely role conflict, role clarity, and role overload (Kahn, Wolfe, Quinn, Snoek, & Rosenthal, 1964; Beehr, Walsh, & Taber, 1976). *Clarity* refers to the extent to which roles are clearly defined and perceived by the employee and role inclarity occurs when an employee does not know what is expected and is unsure of the job content and the methods available to achieve job goals. *Role conflict* results when two or more expectations are incompatible. *Intrarole* conflict results from incompatibility within the set of expectations tied to one job role and *interrole* conflict arises from incompatibility between different roles. Role conflict is also said to exist when work demands action that is incompatible with personal values (Rizzo, House, & Lirtzman, 1970). The current studies included *role conflict* (conflicts between demands and resources, conflicting requests) and *role clarity* (clarity of objectives and expectations at work).

Role conflict is included as a *job demand* in Karasek's Job Content Questionnaire (JCQ; (Karasek et al., 1998)) by the item "I am free from conflicting demands that others make". This instrument is widely used and this implies that results pertaining to job demands to a large degree pertain to role conflict. However, since it is included in a scale also measuring other types of putatively demanding work characteristics, the relative contribution of role conflict remains unknown. If e.g. work amount and role conflict have differential impacts on health the interpretability of results pertaining to the general concept of "job demands" are particularly hampered if the internal consistency of the factor is low. If such is the case "high demands" would sometimes be due to high levels of the role conflict component and other times not. The reliability of the job demands scale has been reported to be low, with the "conflicting demands" item exhibiting a low correlation with the items reflecting time pressure and work amount (see e.g. de Araujo & Karasek, 2008). If "psychological demands" is to be viewed as a uniform concept reflecting aspects of one underlying latent construct it may therefore seem that "conflicting demands" should be separated from the scale and investigated independently of it.

Although very few studies have examined role expectations in relation to musculoskeletal complaints specifically, the health-relatedness of role expectations has been demonstrated. For instance, one study indicated that "role stress" has an effect on depression and somatic health complaints, as well as epinephrine excretion (Fusilier, Ganster, & Mayes, 1987). Studies have suggested that work units in which role conflicts are prevalent also exhibit higher levels of workplace harassment (see e.g. (Hauge et al., 2011)), which is associated with both physical and mental health complaints (Bowling & Beehr, 2006). Furthermore, a few studies have suggested a relationship between occupational role expectations and muscle pain. One research report identified role conflict as a risk factor for the onset of low back pain in a large cohort of the industrial sector in the United Kingdom (Devereux, Rystedt, Kelly, Weston, & Buckle, 2004). That study also identified an association of role conflict with "perceived stress" and claimed this to be the mediating mechanism between role conflict and back pain. Further investigation of a subpopulation from that sample revealed a long term impact (3.5 years) of role conflict and -

ambiguity on saliva cortisol secretion (Rydstedt, Cropley, & Devereux, 2011). A recently published study of a representative sample of Norwegian employees indicated that increasing or prolonged high levels of role conflict over a three-year period increased the risk of new-onset moderate to severe low back pain (Sterud & Tynes, 2013). Incompatibility of demands stemming from work and family ("work-family conflict") has recently become the subject of investigation in a couple of large scale cross-sectional studies of Swiss employees that have reported an association with headaches and backaches (Hammig, Gutzwiller, & Bauer, 2009) and low back pain and neck pain (Hammig, Knecht, Laubli, & Bauer, 2011).

1.5.5. Leadership

In addition to providing social support (as discussed above) the leader of an organizational unit can be the source of psychological resources or challenges through other aspects of the style of leadership that is executed. *Empowering leadership* refers to the degree to which leaders encourage employees to participate in important decisions, to express different opinions, and to develop skills. Contemporary multimodal biopsychosocial approaches to the management of chronic pain often highlight increased self-management of pain and improved pain-coping resources (Roditi & Robinson, 2011). Empowerment is in this respect intrinsically important and may have positive outcomes both through behavioral, cognitive, and affective treatment responses. Little research has considered the effect of leadership that facilitates empowerment on muscle pain. It has been reported *not* to predict sick leave due to musculoskeletal complaints (Bergstrom, Bodin, Bertilsson, & Jensen, 2007). However, negatively appraised leadership styles have been associated with muscle pain (Fjell, Osterberg, Alexanderson, Karlqvist, & Bildt, 2007), and a leadership index comprised of *empowering, fair,* and *supportive leadership* from the QPS_{Nordic} has been linked to health-related quality of life (Lohela, Björklund, Vingard, Hagberg, & Jensen, 2009).

Fair leadership was also included in the current studies and refers to employees' perception of whether the immediate superior distributes work fairly and treats workers equally. Conceptually this is related to *organizational justice*, which has been proposed to be a "new psychosocial predictor of health" (Elovainio et al., 2002). Quite convincingly, organizational justice has been found to explain additional risk of coronary heart disease after adjustment for job strain and effort-reward imbalance, which are also associated with elevated risk (Kivimaki et al., 2005). Research motivated by this focus has mostly been concerned with procedural justice (i.e. fairness of procedures) and relational justice (i.e. fair treatment by coworkers and superiors) (Elovainio, Heponiemi, Sinervo, & Magnavita, 2010). Empirical studies have demonstrated associations of organizational justice with inflammation, sleeping problems, cardiovascular regulation, cognitive impairments, and high rates of work absenteeism (Elovainio et al., 2010). It has also been associated with mental health (Ndjaboue, Brisson, & Vezina, 2012) and acute and chronic non-specific pain (Saastamoinen, Laaksonen, Leino-Arjas, & Lahelma, 2009).

1.5.6. Predictability

The psychological significance of knowing the range of probable work events of the future may be important. Short term predictability was assessed in the current studies by the factor of *predictability during the next month*. This regards the employee's opportunity to generate realistic expectations about events to take place within the next month (i.e. what tasks, coworkers, and superior to expect) (Dallner et al., 2000). If uncertainty pertaining to short term working conditions results in chronic vigilance, sustained psychological and physiological activation may influence health. Although rapid technological and societal changes seem to actualize the role of short term predictability it has been a practically non-existent theme in occupational health research (Dallner et al., 2000). A prospective association has been reported of the single item "do you know in advance what kind of task to expect a month from now" with a change in back pain severity after six months (Lau & Knardahl, 2008). A related concept, job insecurity, has been more extensively studied. Job insecurity refers more globally to uncertainty regarding the continuation of current employment and has exhibited associations, albeit relatively unspecific, with physical and mental health (Sverke, Hellgren, & Naswall, 2002).

1.5.7. Commitment

In the current studies *organizational commitment* referred to the degree of positive feelings about the organization and agreement with perceived organizational values. Employees with high degrees of commitment are those who identify with their workplace and feel that it represents values that they subscribe to. This kind of organizational commitment is a form of *affective* commitment ("I want to work here"), as opposed to *continuance* commitment which centres on the perceived cost of leaving the organization ("I have to work here"), or *normative* commitment which refers to the persuasion that leaving the organization would be morally wrong ("I should work here") (Dallner et al., 2000). Organizational commitment has most often been studied as an outcome of working conditions (see e.g. Mathieu & Zajac, 1990), but has also been suggested to influence health, mainly by acting as a moderator of the "stress-outcome" relationship (Mathieu & Zajac, 1990). For instance, highly committed individuals may be greatly distressed by having to chose between spending time completing work tasks or being with family, implying that commitment exacerbates the consequence of work-family conflict (Mathieu & Zajac, 1990). Possibly, individuals who identify with the organization may be more vulnerable to threats to the organization since it threatens their interest (in the form of e.g. self-image or source of income).

On the other hand, it has also been suggested that commitment is *protective* since it provides individuals with meaning and a sense of coherence that facilitates the coping process when faced with adversity (Antonovsky, 1979). These hypotheses have been dealt with under the heading of "stress", and one could speculate that this is part of the reason for seemingly opposite hypotheses gaining popularity. Whether or not the general claim of "commitment moderates the outcome of stress" is correct may depend on the nature of the challenge (i.e. the "stress") at hand. Some challenges may threaten the organization in general while others may threaten the employee specifically, and sometimes what facilitates organizational development threatens the employee. If the organization is under duress highly committed employees may invest more emotional effort and feel more threatened ("stressed") than employees who care less. However, if the employee is challenged ("stressed") by demands posited by the organization this may appear more meaningful and reasonable to those who are committed to company goals. Furthermore, it seems reasonable to assume that the nature of commitment (i.e. affective, continuance, or normative) influences the response to specific types of exposure. Organizational changes may pose a challenge to individuals with high continuance commitment if associated with job insecurity but perhaps not if associated with change in company strategies and public image. Employees with high affective commitment, on the other hand, may feel more threatened by such changes since it may challenge their view of what the organization should be, and may even threaten aspects of their self-image. Although the main effect of commitment on musculoskeletal health has received little attention, the QPS_{Nordic}-conceptualization of commitment has been shown to predict subjective health after 3,5 (Lohela et al., 2009) and 4 years (Hudek-Knezevic, Krapic, & Maglica, 2009).

1.5.8. Social climate

While the *culture* of an organization can be seen as the acquired shared views and silent, implicit assumptions that form the paradigm for behavior, the organizational *climate* can be understood as the manifestation of culture as a more temporary state of the organization (Moran & Volkwein, 1992). One could perhaps say that if culture is the general *trait* of the organization then climate is the current *state*. Thus, the concepts of culture and climate are related. In the current studies an aspect of organizational climate, the *social climate* of the work unit, was studied. This construct refers to the degree to which the climate in the work unit can be characterized as tense, unsupportive, and distrustful. Many company improvement efforts start with attempts to measure the climate of the organization and work unit. Presumably, social climate is partly a result of working conditions and culture and informal as well as formal structures that influence the social interaction in an organization. As such, it is not very specific and perhaps difficult for employers to modify even if it does seem important both for motivation, well-being, productivity, and perhaps health. Very little research has been undertaken to clarify the relevance of social climate to employee health. Changes in the social climate has been demonstrated to predict improvement of subjective health (Lohela et al., 2009). Furthermore, single items from *social climate* of the QPS_{Nordic} did predict intense or disabling low back pain after three months in a study of nurses' aides in Norway (Eriksen, Bruusgaard, & Knardahl, 2004).

1.5.9. Job satisfaction

It seems reasonable to think that satisfaction with the job as well as with life in general has a potentially fundamental impact on an individual's cognitions, emotions, and ways of coping with challenge. Job satisfaction has been proclaimed to be among the more important occupational predictors of back pain (Hoogendoorn et al., 2000; da Costa & Vieira, 2010b; Macfarlane et al., 2009; Linton, 2001). A 2005 meta-analysis concluded that job dissatisfaction is an important influence on health and that any improvement effort aiming to better employee health should identify factors that improve job satisfaction (Faragher, Cass, & Cooper, 2005). The current studies included a single item global measure of job satisfaction (“overall – how satisfied are you with your job?”). Single item measures to assess psychological constructs have been claimed to be appropriate if the constructs in question are “simple” and unambiguous to the experiencing subject. Single item measures of overall job satisfaction have been empirically related to more complex multi-item measures, and been reported to adequately capture global satisfaction (Wanous, Reichers, & Hudy, 1997). Nevertheless, the concept of satisfaction itself seems context-sensitive, likely to reflect transient well-being (Dallner et al., 2000). Moreover, since people tend to adjust their expectations to the present conditions, satisfaction measures tend to generate skewed distributions, with most people reporting on the “satisfied” end of the scale (Dallner et al., 2000). Thus, the measure of job satisfaction may only be sensitive at the opposite end, i.e. those who report being “rather satisfied” may be a more heterogeneous group than those who report being dissatisfied. Finally, although job satisfaction was included in some of the current studies, it is important to note that this is mainly due to the focus it has received in previous research. The present studies aimed to maintain a focus on exposures that are modifiable. Satisfaction with the job seems to be dependent on a number of other factors, some of them possibly included in the current studies. As such, an interesting theoretical approach could be to assess the role of satisfaction as a mediator of the effects of other factors both separately and in combination. This was considered outside the scope of the current studies but may be an appropriate aim for further research. In practice, many efforts to improve working conditions start with assessments of organizational climate and satisfaction, but in order for such information to be useful it is necessary to also know what factors influence these characteristics of employee perceptions.

1.5.10. Mechanical factors

There are a number of well established mechanical work factors that influence the risk of developing musculoskeletal health complaints (see e.g. Bernard, 1997). Two mechanical factors were included in the current studies to maintain comparability with the psychological and social factors, and also to assess the potential confounding role of physical demands in the relationship of psychological factors with health. The included factors were physical demands and working with arms raised above shoulder level. Exact details of the wording and scoring of the items can be found in the articles. These factors were self-reported and therefore subject to some of the same limitations that can influence the other exposure measures (e.g. overestimation of workload based on experienced symptoms).

2. Study objectives

The primary overall aim of the projects of the current thesis was to elucidate the ways in which psychological conditions at work may influence health complaints characterized by somatic pain. In order to attain such knowledge a comprehensive set of occupational psychological and social exposure factors were studied as predictors of the intensity, severity, and occurrence of neck pain, back pain, and headache. Emphasis was placed on expanding the scope to acquire knowledge about specific factors that have rarely been studied in this research context and to enable the comparison of these factors with factors more frequently studied. Also, the common approach of assessing exposure at baseline only was compared with the less common approach of utilizing information about exposure at several time points.

Specific aims of the individual studies were:

Study I aimed to identify predictors of *neck pain intensity* after two years in a diverse sample of Norwegian employees. A comprehensive range of exposures was studied and neck pain intensity was measured on an ordinal scale to avoid information loss. Baseline-adjusted neck pain intensity at follow-up was predicted from baseline exposures as well as baseline and follow-up exposure combined. The risk of new-onset pain or persistent pain at follow-up was also assessed.

Study II aimed to identify predictors of *back pain severity* after two years in a diverse sample of Norwegian employees. The same comprehensive range of exposures as in study I was employed, adding *job satisfaction*. The outcome was a composite of back pain *intensity* and *duration*. The predictive ability of baseline exposures was compared with the predictive ability of measures of exposure across the two time points.

Study III aimed to identify predictors of *headache severity* after two years in a diverse sample of Norwegian employees. The same comprehensive range of exposures as in study II was employed. The outcome variable was a composite of headache *intensity* and *duration*. Baseline –adjusted headache severity at follow-up was regressed both on baseline exposure the average of baseline- and follow-up exposure. Furthermore, causal models were tested to judge the relative tenability of *normal*, *reverse*, and *reciprocal* causality assumptions as explanations of the results of the previous regressions.

Study IV aimed to assess the effect of different developments of exposure over time on the incidence and perseverance of *neck pain*. Employees were followed over a period of four years (three time points). Five factors were selected that had previously been studied in study I to evaluate whether the significance changed when assessed over a longer time period. Employees reporting neck pain at baseline and employees reporting no neck pain at baseline were assessed separately to evaluate whether exposure factors differed as risk- and prognostic factors.

3. Material and methods

3.1. Recruitment procedure

The studies of the current thesis gathered data by work environment surveys conducted in a wide variety of organizations in Norway. All studies were part of the ongoing longitudinal research project “The new work place: Work, health, and participation in the new work life” at The National Institute of Occupational Health. The general aim of this comprehensive project was to obtain new knowledge about working conditions of consequence for employee health and work ability over time. The surveys gathered data by web-based questionnaires that were identical for all participants in all companies across all time points. Companies received written reports of results as a tool for organizational development and an aid for monitoring the organizational work environment. Presentations were given prior to the survey to communicate the study aims. The survey was web-based, although participants were given the option of filling out a paper version. The questionnaire consisted of items covering a wide range of physical, psychological, and organizational factors as well as aspects of both somatic and mental health. Since the project required gathering and storing personal information about health and perceptions of working conditions, responses were treated confidentially in accordance with a specific license given by the Norwegian Data Inspectorate. Participation was voluntary after informed consent.

3.2. Subjects

All studies included in the thesis analyzed data gathered by the same project. However, the different studies analyzed samples that were obtained at different points in time. Hence, the samples differed between studies, although partially overlapping. Subject characteristics for employees that fulfilled inclusion criteria for prospective analyses in the different studies are given in table 1.

Table 1. Subject characteristics at baseline for employees that responded at more than one time point (repeated responders)*.

	Study I: Neck pain (n=2419)		Study II: Back pain (n=2808)		Study III: Headache (n=3574)**		Study IV: Neck pain (n=1250)	
Age								
<30	126	(5.2 %)	166	(5.9 %)	209	(5.8 %)	73	(5.8 %)
30-39	609	(25.2 %)	696	(24.8 %)	894	(25.0 %)	378	(30.2 %)
40-49	821	(33.9 %)	908	(32.3 %)	1153	(32.3 %)	439	(35.1 %)
50-59	722	(29.8 %)	850	(30.3 %)	1078	(30.2 %)	309	(24.7 %)
>59	141	(5.8 %)	188	(6.7 %)	240	(6.7 %)	51	(4.1 %)
Sex								
Male	877	(36.3 %)	1090	(38.8 %)	1371	(38.4 %)	594	(47.5 %)
Female	1542	(63.7 %)	1718	(61.2 %)	2203	(61.6 %)	656	(52.5 %)
Classification of occupation								
Legislators, senior officials and managers	225	(9.5 %)	296	(10.7 %)	380	(10.6 %)	126	(10.2 %)
Professionals	383	(16.1 %)	608	(22.0 %)	962	(26.9 %)	315	(25.5 %)
Technicians and associate professionals	1100	(46.2 %)	1118	(40.4 %)	1331	(37.2 %)	595	(48.1 %)
Clerks	172	(7.2 %)	209	(7.6 %)	270	(7.6 %)	110	(8.9 %)
Service workers and shop and market sales workers	429	(18.0 %)	461	(16.7 %)	520	(14.6 %)	77	(6.2 %)
Skilled agricultural and fishery workers	1	(0.0 %)	1	(0.0 %)	7	(0.2 %)	0	(0.0 %)
Craft and related trades workers	26	(1.1 %)	26	(0.9 %)	43	(1.2 %)	0	(0.0 %)
Plant and machine operators and assemblers	3	(0.1 %)	3	(0.1 %)	5	(0.1 %)	1	(0.1 %)
Elementary occupations	40	(1.7 %)	44	(1.6 %)	57	(1.6 %)	13	(1.1 %)
Armed forces and unspecified	0	(0.0 %)	0	(0.0 %)	0	(0.0 %)	0	(0.0 %)
Missing values	40	-	42	-	-	-	13	-
Complaint intensity, previous 4 weeks	**Neck pain:**		**Back pain:**		**Headache:**		**Neck pain:**	
Not troubled	1260	(52.1 %)	1625	(57.9 %)	1878	(52.5 %)	574	(50.0 %)
A little troubled	715	(29.6 %)	766	(27.3 %)	1087	(30.4 %)	351	(30.6 %)
Rather intensely troubled	378	(15.6 %)	342	(12.2 %)	508	(14.2 %)	196	(17.1 %)
Very intensely troubled	66	(2.7 %)	75	(2.7 %)	101	(2.8 %)	27	(2.4 %)
Missing values[a]	-	-	-	-	-	-	102	-
Complaint duration, previous 4 weeks								
None	1260	(52.7 %)	1625	(57.9 %)	1878	(52.5 %)	574	(50.0 %)
1-5 days	666	(27.8 %)	658	(23.4 %)	1283	(35.9 %)	336	(29.8 %)
6-10 days	229	(9.6 %)	241	(8.6 %)	280	(7.8 %)	113	(10.0 %)
11-14 days	103	(4.3 %)	110	(3.9 %)	77	(2.2 %)	43	(3.8 %)
15-28 days	135	(5.6 %)	174	(6.2 %)	56	(1.6 %)	62	(5.5 %)
Missing values [a]	26	-	-	-	-	-	122	-

*In study I and study II subjects were defined as repeated responders if they completed at least one predictor in addition to pain at both time points. In study III the criterion for repeated response was different due to the multiple imputation procedure employed to handle missing data; hence repeated response was defined as the completion of one item relevant to the study at each time point. In study IV the inclusion criterion was

(continued on next page)

response to at least one relevant item in at least two waves.
**Missing data in study III were handled by multiple imputation; subject characteristics are thus expressed as pooled estimates across the multiple imputed datasets. Sums may deviate from 3574 due to rounding
[a] In paper IV responding to the neck pain question was not an inclusion criterion and therefore some values are missing for the neck pain item. Since only neck pain *intensity* and *occurrence* were studied in paper I and IV, the inclusion criteria did not encompass neck pain *duration* and therefore some values are missing for this item as well.

3.3. Design

Studies I-III utilized two-wave full panel designs (i.e. all variables were measured at both measurement occasions) to identify predictors of *neck pain intensity* (study I), *back pain severity* (intensity multiplied with duration) (study II), and *headache severity* (intensity multiplied with duration) (study III). The average follow-up period from end of baseline to end of follow-up was 23 months (range 17 – 36) in all studies.

Cross-sectional as well as prospective analyses were conducted. The cross-sectional samples also included employees that were invited at only one of the time points, i.e. employees that left or entered the companies during the follow-up period. Thus, the three types of sample (baseline cross-sectional, follow-up cross-sectional, and prospective) encompassed different populations and provided a basis upon which to evaluate the consistency of the observed associations. Also, it should be noted that although prospective analyses are vital to support causal assumptions some exposure-health mechanisms may be more accurately reflected by point-estimated associations. According to an *initial impact model,* exposure factors can have almost immediate direct effects on health and well-being (Frese & Zapf, 1988). One could, for instance, speculate that some factors influence cognition and thinking to modulate pain in the short term. Negative appraisal of bodily sensations may contribute to the interpretation of benign sensations as symptoms of disease, and thereby induce pain catastrophizing that initiates a nocebo response that increases the likelihood of significant pain occurring.

A wide variety of psychological and social factors and two self-reported mechanical exposures were studied in order to map predictors of the different pain complaints. An important general aim of each study was to assess the relative importance of predictors among a variety of different factors measured in the same sample. Most previous studies have investigated specific models by a few factors (often job demands, decision control, and supervisory support), or attempted to reach general conclusions pertaining to "the psychosocial work environment" based on a few factors.

3.4. Measurement of pain

The outcome measures were obtained from a symptom checklist that encompassed a variety of different health complaints (Steingrimsdottir et al., 2004). Thus, the *intensities* of 21 different health complaints were assessed by asking "have you been troubled by… (e.g. neck pain) the last 4 weeks?", with optional answers "not troubled" (1), "a little troubled" (2), "rather intensely troubled" (3), and "very intensely troubled" (4). Subjects reporting pain were then presented with items regarding the *duration* of the pain complaint the last 4 weeks: "1-5 days" (1), "6-10 days" (2), "11-14 days" (3), and "15-28 days" (4). In Norwegian language the wording "troubled by" is a common way of expressing that one has experienced a symptom. Intensity and duration were highly correlated.

In some analyses a complaint severity index was constructed by multiplying intensity with duration, according to the method described by Steingrimsdottir and coworkers (Steingrimsdottir et al., 2004). This strategy was based on the notion that subjects may consider light or moderate pain that endures for prolonged periods of time to be as severe as brief instances of intense pain. Analyses of intensity and severity made use of the full range of the outcome variables. In study IV the *occurrence* of neck pain was investigated by classifying reports of "a little troubled", "rather intensely troubled", or "very intensely troubled" as pain occurrence.

Thus, Study *I* investigated neck pain *intensity*, *Study II* investigated back pain *severity, study III* investigated headache *severity,* and study IV investigated neck pain *occurrence*.

3.5. Measurement of exposure

3.5.1. Scale construction

Descriptions of and theoretical justifications for the included exposure factors are given above in the introduction section. Studies I-III considered the same psychological and social factors, with the exception of *job satisfaction*, which was not included in the first study. In study IV a more narrow selection of factors was chosen based on results from study I to facilitate a more in-depth exploration of exposure over time. Although it would have been interesting to study all the previously investigated factors utilizing the methods of study IV, five factors were chosen, some that were found to be important in the previous studies and some that were not found to be as important. Hence, study IV included *quantitative demands, role conflict, social climate, decision control,* and *empowering leadership.*

All scales from the QPS_{Nordic} comprised 3-5 questions. Items measured frequency of occurrence in the following way: “1=Very seldom or never”, “2=Somewhat seldom”, “3=Sometimes”, “4=Somewhat often”, and “5=Very often or always”. Scales were computed as the mean of the corresponding items. Global *job satisfaction* was measured by the single item: “How satisfied are you with your job – all in all?”. Response categories were “1=Very dissatisfied”, “2=Dissatisfied”, “3=Satisfied”, and “4=Very satisfied”.

Two self-reported mechanical exposures were analyzed. *Physical workload* was measured by a scale constructed from three items under the heading “to what degree do your work tasks consist of; ...”. The items were “lifting or handling objects that weigh approximately 1-5 kilograms with your own muscular strength”, “lifting or handling objects that weigh approximately 6-15 kilograms with your own muscular strength”, “lifting or handling objects that weigh more than approximately 15 kilograms with your own muscular strength”. Response categories were “1=Seldom or never”, “2=Sometimes”, “3=Daily”, and “4=Many times pr. day”. Reliability coefficients for this scale were α=0.90 in study I and α=0.89 in studies II-III. The scale was negatively associated with quantitative demands. This provides discriminant validity and indicates that the quantitative demands scale is not confounded by physical demands. The second mechanical factor was *working with arms raised,* measured with the single item “work positions where you have to raise your arms to or above shoulder level”, under the same response categories as physical workload.

3.5.2. Classification of exposure

In *studies I-III* exposure factors were categorized to observe the effect of different levels separately as well as linear trends. This may be important if some factors exhibit distinct non-linear effects, such as threshold effects or curvilinear effects, in which case analyses based on assumptions of linearity may not detect present effects. The exposure scales ranged from 1 to 5, and were classified according to the following: Scores between 1.00-1.80 were assigned the value “1”, scores between 1.81-2.60 the value “2”, scores between 2.61-3.40 the value “3”, scores between 3.41-4.20 the value “4”, and scores between 4.21-5.00 the value “5”. For some variables this resulted in few observations of the category used as reference in the regression analyses. Therefore, some categories were collapsed in an attempt to enhance statistical power. However, it should be noted that this strategy may not be successful since the necessary contrast in exposure to detect difference in risk may be lost.

3.5.3. Longitudinal exposure modeling

The way in which the effects of exposures over time were studied varied somewhat between studies (see table 2 for an overview). All studies estimated the effect of *baseline exposure* on subsequent stability-adjusted pain. *Studies I-III* studied the effect of *average* exposure over two time points. In addition to this, *studies I-II* studied *change variables* constructed on the basis of exposure measures from two time points. In *study III cross-lagged* and *synchronous models* were studied to assess reciprocal and reverse effects. Finally, in *study IV* exposure over three time points was studied by *group-based trajectory models.*

Table 2. Overview of strategies employed in the different studies to model the prospective relation of psychological and social work exposures with the different pain complaints

Modeling strategy:	Study I, Neck pain intensity	Study II, Back pain severity	Study III, Headache severity	Study IV, Neck pain occurrence
Baseline exposure	S	S	S	S
Averaged exposure	S	S	S	NS
Change variables	S	S	NS	NS
Cross-lagged and synchronous models	NS	NS	S	NS
Group-based trajectory models	NS	NS	NS	S

S = Studied

NS = Not studied

3.5.3.1. Baseline exposure

To enhance comparability with previous research the basic approach of regressing pain at T2 on exposure at T1, adjusting for pain at T1, was employed for both continuous and categorized exposure measures.

3.5.3.2. Averaged exposure

Effects of *exposure over time* on subsequent pain was assessed by averaging baseline and follow-up exposure measures. The resulting scales were also categorized according to the procedure described in the previous paragraph. The four-level single items of *job satisfaction* and *working with arms raised over or above shoulder level* were averaged and recoded in the following way: "1.00-1.50" set to "1", "1.51-2.50" set to "2", "2.51-3.50" set to "3", and "3.51-4.00" set to "4".

3.5.3.3. Change variables

Prolonged or changed exposure was investigated by further categorizations to reflect exposure development from baseline to follow-up. Hence, the categorized exposure measures were condensed to reflect “low” (1 and 2), “middle” (3), and “high” (4 and 5) exposure. Any change across these categories from baseline to follow-up was considered a change. Thus, the resulting categories were denoted “constant low”, “decrease”, “constant middle”, “increase”, and “constant high”. Single item variables with four categories were dichotomized into “low (1 and 2)” and “high (3 and 4)”. Measures from T1 and T2 were then combined into “constant low”, “decrease”, “increase”, and “constant high”. Some categories were collapsed due to few observations in the reference category.

Some limitations of the change variable construction strategy must be noted to discourage overinterpretation of results. (1) Although the sample size was fairly large a limited number of employees exhibited some patterns of exposure over time. This is a consequence of the considerable stability of exposure measures. Consequently, a limited level of detail in classification was possible. This may result in the “decrease” and “increase” groups not exhibiting enough change to reliably detect effects. (2) The effect of changed exposure may depend on previous levels of exposure. It seems reasonable to assume that alleviation of an adverse exposure may affect health differently from a decrease from an exposure level that is not harmful. The exact level of exposure from which alleviation is needed to rehabilitate health is unknown. More detailed classification was not possible due to the aforementioned statistical power issues.

The change variable construction in study II differed slightly from that in study I. This was done in an attempt to address the abovementioned concern of skewed distributions. Thus, *tertile splits* were employed to create equally sized groups with “*low*”, “*middle*”, and “*high*” levels of exposure at baseline and follow-up, and change was categorized as described above. Although this strategy ensures a more even distribution of subjects across categories it introduces other limitations inherent to the data. Employing tertiles to classify exposure may result in insufficient exposure contrast at each time point – differences in exposure between the lower and higher thirds of the sample may be too small to detect health effects.

3.5.3.4. Cross-lagged and synchronous models

In study III factors that were associated with headache in all prior analyses were further explored to judge the tenability of some competing causal assumptions that could explain the prospective associations. *Lagged* effects (i.e. when *T1* exposure is associated with *T2* health) obtained by regressing health at T2 on exposure at T1 may support a notion of causal influence from exposure on health, but does not effectively rule out some plausible alternative explanations. For instance, "reverse" causality (health influences exposure perception or reporting) could be present. If so, previous exposure may predict future health but assuming a causal influence from exposure to health would be unwarranted. *Cross-lagged* and *synchronous* models (de Lange, Taris, Kompier, Houtman, & Bongers, 2003; Zapf et al., 1996; Finkel, 1995) analytically separate alternative sources of covariance between exposure and outcome across time. This allows the comparison of alternative causal hypotheses. Figures 1 and 2 of study III illustrate the different causal assumptions that can explain prospective associations of work exposures and health complaints.

When referring to causality a note of caution is warranted. Full panel designs can add considerable insight to the issue of causality, and are superior to approaches that include information about exposure variables at one time point only. They cannot, however, prove the *presence* of causality. The strength of cross-lagged and synchronous models is that they allow the comparison of the statistical fit of different models based on different causal assumptions. However, this does not preclude the possibility of third factors that cause both exposure and outcome to occur with the temporal pattern observed in a given observational study (Zapf et al., 1996).

In study III the tenability of four competing cross-lagged and four competing synchronous models were evaluated. The different cross-lagged models can be summarized by the following: (1) A *stability model* (M1) includes only the stability of exposure and outcome, and only cross-sectional associations link exposure with outcome, (2) A *normal causality model* (M2) includes stabilities as well as an effect from T1 exposure to T2 outcome, (3) A *reverse causality model* (M3) includes stabilities as well as an effect from T1 outcome to T2 exposure, (4) A *reciprocal causality model* (M4) includes “stability” paths as well as both “normal” and “reverse” cross-lagged paths. These models are *nested,* i.e. the less complex models can be derived from the more general models simply by removing effect paths (M1 is nested in M2 and M3, and M1, M2, and M3 are nested in M4). Nested models can be compared to evaluate whether adding effect paths results in models that improve the explanation of the empirical data to an extent that justifies the added complexity and loss of parsimony.

Cross-lagged models estimate the impact of T1 exposure on T2 outcome after partialling out the stabilities of both. This strategy runs the risk of underestimating health effects that stem from pathogenic mechanisms that have a shorter time span than the duration of the follow-up period (Finkel, 1995). *Synchronous models* may counteract this problem by including regression paths from *T2* exposure to *T2* outcome and vice versa instead of across time. That is, the relationship between variables at follow-up is estimated after partialling out stability over time.

3.5.3.5. Group-based trajectory modeling

In study IV three measurement occasions were included, providing opportunities to explore development of exposure over time and the effects of different development profiles on the occurrence of neck pain. Thus, Group-Based Trajectory Modeling (GBTM) (Nagin & Odgers, 2010; Nagin, 1999), also known as Latent Class Growth Analysis (LCGA) (Muthen & Muthen, 2000) or Latent Class Growth Modeling (LCGM) (Andruff, Carraro, Thompson, Gaudreau, & Louvet, 2009) was employed to distinguish between clusters of similar response over time. Hence, individuals were grouped together based on the initial level (intercept) and subsequent development (slope) of the different exposures. These "latent trajectory groups" are not directly observed but inferred from sample heterogeneity. After identifying trajectory groups the odds of neck pain after four years could be compared between groups. This was done both for subjects reporting neck pain at T1 and those not reporting neck pain at T1. Thus, the impact of exposure development on both risk and prognosis of neck pain was assessed.

3.6. Confounders

Age, *sex*, and *baseline levels of the outcomes* were treated as confounders and thus adjusted for in all regressions. Age was classified into the age groups "<30", "30-39", "40-49", "50-59", and ">59".

Skill level was adjusted for in all multivariate regressions of study II and III. Skill levels were determined according to the ISCED (International Standard for Classification of Education) classification that reflects the normal educational requirements in different occupations. This classification was based on the Norwegian standard classification of occupations (STYRK) which has been developed by Statistics Norway based on the International Standard Classification of Occupation (ISCO-88). These classifications were provided by the companies prior to the surveys. Thus, five skill levels were determined: 1 = Occupations that normally require education equivalent to a first or postgraduate university degree, or college exams based on a similar length of study (>16 years), 2 = Occupations that normally require 1-3 years of education at university or college level (but not equivalent to a first university) (13-15 years), 3 = Occupations that normally require 1-3 years of secondary education (10-12 years), 4 = Occupations that require no more than 9 years of primary education, 5 = Unspecified (occupations in which the level of required education may vary substantially). Since the unspecified category reflects varying degrees of educational attainment the skill level variable was treated as nominal. Additionally, in study III *smoking* was assessed by asking ¨approximately how many cigarettes/cigars/pipes do you smoke during a normal week?¨, with the response categories ¨0¨, ¨1 – 6¨, ¨7 – 35¨, ¨36 – 70¨, ¨71 – 140¨, ¨>140¨.

In addition to the "standard" confounders, regressions were adjusted for other exposure factors that were estimated to have an impact on the exposure-outcome association. This procedure is further described below.

3.7. Statistical analyses

Analyses were conducted using SPSS statistics (IBM, Armonk, NY, USA) and MPLUS (Muthén & Muthén, 2012).

3.7.1. Non-response analyses

All four studies estimated the extent to which selection based on the studied variables may have occurred. Binary logistic regressions were run to compare the odds of responding with the odds of not responding at baseline based on sex and age group. These analyses were based on information attained from the companies prior to conducting the surveys.

Attrition analyses were also conducted to assess selective dropout after the first wave of the studies. Thus, response vs. non-response at the follow-up time points were regressed on all independent variables among employees that did respond at baseline.

3.7.2. Regression analyses

Baseline, averaged, and change predictors of pain were estimated by ordinal logistic regressions. Cumulative odds ratios were thus calculated to express the difference in odds of the outcome being above vs. below each possible cut point (e.g. pain severity of 2-16 vs. 1, 3-16 vs. 1-2, 4-16 vs. 1-3, and so on) pr. unit change of a predictor (Kleinbaum & Klein, 2002). Ordinal regression obtains one single odds ratio under the assumption that it is equal across all cutpoints of the outcome (the proportional odds assumption) (Kleinbaum & Klein, 2002). For a categorical independent variable the odds of higher outcome for each separate group defined by the categories are compared with the odds for the group defined by the reference category.

Some studies mutually adjust for all independent factors in order to identify factors that can be considered “core predictors”. That is, factors that exhibit statistically significant unique contributions to explained variance in the outcome are considered the substantively most interesting explanatory factors. Importantly, this presupposes either that control variables are not implicated in the mechanism mediating the effect of exposure on outcome, or that interest is in uncovering only *direct* effects of exposure on outcome. Adjusting for variables that are part of the causal chain between exposure and outcome (commonly referred to as mediators or intervening variables) will induce *overadjustment bias* (Schisterman, Cole, & Platt, 2009). The potential pitfalls of overadjustment include precision loss (even if estimates are unbiased confidence intervals may be wide) and attenuated effect estimates (Schisterman et al., 2009). Naturally, the risk of unnecessary adjustment is exacerbated when the number of potential control variables increases. In the current studies the magnitude of possible confounding effects of the psychological, social, and mechanical factors on each other was estimated. Factors were entered as control variables if this magnitude exceeded a certain threshold, as recommended by Rothman and Greenland (Rothman & Greenland, 1998). First, outcome was regressed on each independent variable in the baseline sample. Then, these crude effect estimates were separately adjusted for every other factor. If this produced a change of more than 10 per cent in the effect estimates, the corresponding factor was controlled for in subsequent analyses. This strategy should account for confounding when it is present. However, it should be noted that this data-driven procedure has considerable limitations. It was employed in absence of theoretical guidance to suggest which other work factors should be controlled. Compared to mutual adjustment for all other variables it may reduce the risk of unnecessary confounder adjustment. However, it may not avoid overadjustment bias due to entering mediating variables as covariates. In fact, this confounder selection procedure constitutes one step in the classic Baron and Kenny mediation test (Baron & Kenny, 1986). Thus, this strategy for confounder adjustment may be considered a conservative approach.

One central aim of the current studies was to identify predictors among a comprehensive set of candidate factors – thus multiple testing introduced the concern of possibly capitalizing on chance. To reduce this threat a conservative approach was chosen by calculating 99% confidence intervals and the Bonferroni-adjusted significance level. This threshold was calculated by dividing the overall significance level by the number of factors tested (e.g. 0.01/16=0.0006).

3.7.3. Cross-lagged and synchronous models

In study III causal analyses were conducted by structural equation modeling (SEM) of latent variables. Basically, "latent variables" are constructs that are represented by the shared variance of multiple items (see e.g. (Muthén, 2002) for a brief overview of latent variable modeling). For instance, the variance of a psychological, non-observable construct such as e.g. depression can be inferred by using factor analysis to extract the shared variance of a number of items corresponding to a scale. This is based on the assumption that the variation in the observed items of a factor measure is caused by (1) a common factor (e.g. depression), (2) item-unique "residual" influences (i.e. specific events that influence the response to a particular item), and (3) random error influencing each item. Thus, the factor analysis extracts the reliable part of the measure and corrects for several sources of measurement error. The latent variables can then be included in a set of simultaneously specified regressions to relate the latent variables to each other (i.e. a set of "structural equations"). Thus, in study III the selected psychological exposure factors were modeled as latent variables operationalized by the items corresponding to each factor, and headache severity was modeled as a latent variable operationalized by the intensity and duration items as observed indicators. A robust weighted least squares estimator (WLSMV) was employed (Muthén & Muthén, 2012). This is appropriate with ordered categorical items that are non-normally distributed (see e.g. Flora & Curran, 2004; Muthén, 1984).

Overall model fit was judged by several fit indices: The comparative fit index (CFI; values >0.90 indicate acceptable fit, >0.95 good fit (Llabre, 2010; Schreiber, Nora, Stage, Barlow, & King, 2006)), the root mean square of approximation (RMSEA; values <0.06 indicate good fit (Llabre, 2010; Schreiber et al., 2006)), and the Tucker-Lewis index (TLI; values >0.96 indicate good fit (Schreiber et al., 2006)). Nested models were compared to evaluate the relative utility of the *stability* model, the *normal* causality model, the *reverse* causality model, and the *reciprocal* causality model in explaining the data (see figures 2 and 3 of study III). Comparisons were performed by robust chi-square difference tests (the DIFFTEST option of Mplus) (Muthén & Muthén, 2012). These tests balance the lost degrees of freedom of a more complex model with the added explanatory value.

The first step of assessing the formulated models consisted in testing the assumption of longitudinal factorial invariance (Little, Preacher, Selig, & Card, 2007). For the modeling of repeated measures to validly reflect information about processes that take place over time it is necessary that the employed measures represent the same factors across time. Otherwise, different scores at different measurement occasions could be a consequence of an unreliable measurement method and thus results could be invalid. The latent variable approach allows testing the assumption of longitudinal measurement invariance. Thus, chi-square difference tests were conducted to test whether an "invariance model" assuming equal factor loadings (i.e. the regressions of items on their respective latent factors were constrained to equality across time points) was as successful in explaining the data as a "variance model" in which factor loadings were allowed to vary across time points. This procedure supported the assumption of factorial invariance for all the factors involved in cross-lagged and synchronous models except *control over work intensity* (analyses not shown). For this factor the weaker assumption of *configural invariance* (i.e. equal patterns of factor loadings across time) was supported. Interpretations of results pertaining to control over work intensity may take this into account. However, chi-square difference tests are known to be sensitive to type I error. Thus, the significance of a difference in model fit between a model of invariance vs. variance of factor loadings may be overstated. Therefore, it has been proposed that a difference in the overall model fit index CFI of more than 0.01 is a more appropriate cutoff for rejecting the hypothesis of factorial invariance (Cheung & Rensvold, 2002). The CFI for the "invariance model" and the "variance model" were identical.

In addition to the latent variables being regressed on themselves across time to model their stability, each item was regressed on itself across time. This means that in addition to including the autoregression of the shared variance of each set of variables pertaining to a factor the autoregressions of residual ("error") variance of each item was modeled. This was done because items used to measure factors may also exhibit systematic error variance that is stable across time. Also, residual variances of exposure and outcome at T2 were allowed to correlate. This takes into account that exposure and outcome may be associated for reasons that are not explicitly included in the model. That is, third factors could influence both exposure and outcome at T2 and cause shared residual variance, i.e. covariance between exposure and outcome items at T2 that is not explained by the other variables included in the model. In addition, the previously estimated confounders were regressed on T1 exposure and health in each model. This assumes that confounder effects are stable over time and reflected by baseline exposure/outcome associations (Little et al., 2007). Smoking was included in the previous regression analyses in study III but proved to be consistently unrelated to headache. Therefore, smoking was omitted as a confounder in the cross-lagged and synchronous models to reduce model complexity. Also, it should be noted that the inclusion of health-related behaviors such as smoking may be inappropriate since they may represent behavioral mechanisms by which work exposures influence health.

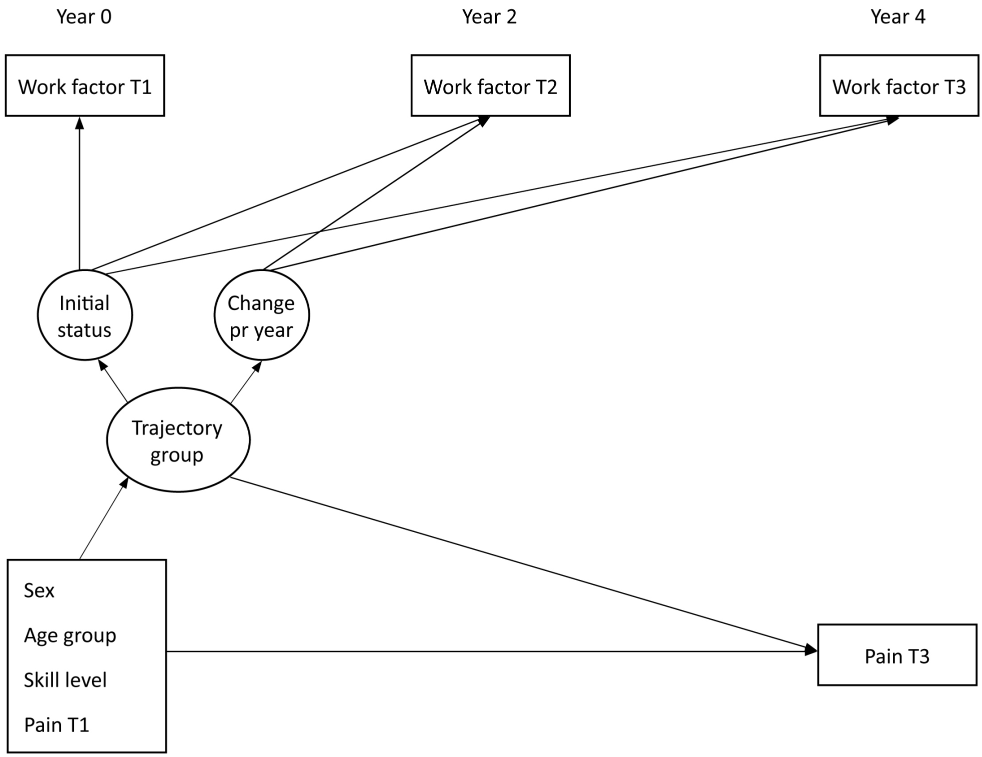
3.7.4. *Group-based trajectory models*

Study IV employed group-based trajectory models (GBTMs) (Nagin & Odgers, 2010). GBTM, also known as *latent class growth analysis* (LCGA) (Muthen & Muthen, 2000), is a class of models that enable distinction between groups of subjects that exhibit different development trajectories. LCGA is based on *latent class analysis* (LCA), which is a method for handling and describing heterogeneity in data by postulating *categorical latent variables* that identify groups of individuals with similar combinations of variable values. Similar to factor analysis, this technique identifies "underlying" sources of covariance. In the case of LCA the patterns of observed responses are seen as generated by underlying categorical variables called "latent classes". These classes designate groups that are not directly observed, but inferred from the clustering patterns of characteristics of subjects in a sample. It is a *person-centered* approach, focusing on the grouping of individuals, rather than a *variable*-centered analysis such as factor analysis. LCA is often used to describe patterns of *different* variables in cross-sectional data. LCGA, however, defines classes by patterns of the *same* variables at different measurement occasions. This results in a description of how a variable changes over time and groups consist of subjects with similar in this respect. *Growth curves* are thus estimated that are allowed vary between these groups. These curves are expressed as the combination of intercept (initial mean) and slope (change in mean pr. time unit) for each group.

Prior to running a model the number of trajectory groups must be specified. The appropriate number of groups is determined by running and comparing a series of models with different numbers of classes/groups. A combination of statistical tests can then be utilized to aid this process of class enumeration. The *Bayesian Information Criterion* (BIC) and the *Bootstrapped Likelihood Ratio Test* (BLRT) were employed for this purpose in the current study (Nylund, Asparouhov, & Muthen, 2007). A smaller BIC indicates better model fit and a p-value of less than 0.05 for the BLRT indicated that a model with *k* classes fits better than the model with *k-1* classes. Moreover, trajectories were inspected to ensure interpretability and utility of distinct trajectory shapes, and the number of subjects assigned to each group was also assessed. While statistical tests can aid the process of group enumeration they must be accompanied by substantive evaluation of interpretability, utility and parsimony of the extracted model (Nagin & Odgers, 2010; Muthen & Muthen, 2000).

After identifying different exposure development groups the models were extended to include neck pain occurrence varying between the groups (see figure 1 below for the complete estimated models). Odds ratios and 95 % confidence intervals were computed to determine whether subjects in different groups exhibited different odds of neck pain. These models were first estimated for all subjects, adjusted for pain at T1. Then, the same model was estimated for subjects that reported no pain at the first time point in order to estimate the risk of *incidence/new-onset* pain during the follow-up period (*risk factors*). Finally, the *persistence* of pain was assessed by estimating the model for subjects that reported having pain at time 1 (*prognostic factors*).

Figure 1. A group-based trajectory model including pain as a function of trajectory group membership and covariates.



3.7.5. Handling of missing data

When evaluating the treatment of missing data it should be kept in mind that the questionnaire from which data was gathered was comprehensive, designed to answer many questions not directly related to the current studies. Thus, participation was defined based on the items included in each separate study and not on all items of the administered questionnaire form. Hence, “missing data” refers to potential item responses that were not completed by subjects that did complete other items of the respective study.

Missing data were handled in slightly different ways in the different studies. In *study I,* scale scores were computed only for subjects that completed all items of the corresponding scales. Analyses were thus conducted for subjects that completed the factors involved in each separate regression. The amount of missing data increased gradually throughout the questionnaire. Therefore, to reduce data loss due to items placed in the latter part of the form, this strategy was chosen instead of listwise deletion. As a result, N varies for different factors studied. This increases statistical power but may decrease comparability across analyses. In *study II* the same strategy was employed except scale scores were computed for subjects that completed at least half of the items corresponding to a scale.

In study III *multiple imputation* (MI) was employed. The more commonly employed *complete case analysis* that is conducted after *listwise deletion* of incomplete cases is based on fairly strong assumptions (i.e. completely random item non-response) and suffers from unnecessary data loss (Graham, 2009). Therefore, to benefit from all present data, imputed datasets were generated by MI (Schafer & Graham, 2002; Graham, 2009). Imputation was conducted with SPSS 19, employing a Fully Conditional Specification, also called Multiple Imputation by Chained Equations (MICE), which is appropriate when no joint distribution can be specified (van Buuren, 2007; Azur, Stuart, Frangakis, & Leaf, 2011). To estimate the statistical properties of the missing data a series of regressions are conducted using all present data to predict missing data. During this procedure error variance is estimated and random error is added to account for the uncertainty of the estimation procedure. From this several different datasets (i.e. multiple imputed datasets) are generated that reflect the statistical properties of the full dataset (observed plus missing item values) as well as error variance within and between datasets. Together this constitutes a multiply imputed dataset. Analyses can be carried out on this dataset by conducting separate analyses on each separate dataset and then combining the parameter estimates according to specific rules that reflect the within and between variability of datasets (Rubin, 1987). Since all observed information is used to estimate parameters MI reduces bias, assuming data are "missing at random" (MAR). MAR means that missingness is a function of observed data, which in turn implies that observed data reflect information about the statistical properties of missing data (Graham, 2009; Schafer & Graham, 2002). In other words it is appropriate if subjects do not complete certain items for reasons that are related to the items that they *did* complete. This assumption is less stringent than the "missing completely at random" (MCAR) assumption that is necessary for listwise deletion to be unbiased (Schafer & Graham, 2002; Graham, 2009). MCAR implies that the reasons for not responding to certain items are completely unrelated to all other items.

Thus, in study III 10 imputed datasets were generated for each cross-sectional sample. Hence, the baseline sample and the follow-up sample were separately imputed for all subjects that had responded to a minimum of one item relevant to the study. In addition to this, a longitudinal dataset was imputed for employees that completed at least one relevant item at *both* time points. The amount of missing information that was imputed (i.e. *item* non- response among participants that did respond to at least one item) comprised 4.1 % of possible item responses in both the baseline and follow-up samples. In the longitudinal sample 3.1 % of items responses were missing. All variables of the study were included in the imputation model as independent and dependent variables.

In *study IV* missing data were handled by Full Information Maximum Likelihood (FIML) (Enders, 2010), employing a robust maximum likelihood estimator (MLR) in MPLUS (Muthén & Muthén, 2012). Similar to MI, FIML utilizes all observed data under the MAR assumption. But unlike MI, it does not require the generation of imputed datasets prior to the analysis. Missing data properties are estimated while running the model and missingness information is derived from the formulated model. When estimating complex models FIML is considerably less demanding to implement than MI and according to Olsen and Schafer the two approaches are comparable in efficiency when sample sizes are "reasonably large" (Olsen & Schafer, 1998).

4. Results

In this section the results from each paper included in the current thesis are presented. Main results are presented to give an overview of the findings of each study. Additional details are reported in the respective papers.

4.1. Paper I

Christensen JO, Knardahl S. Work and neck pain: A prospective study of psychological, social, and mechanical risk factors. Pain 2010;151(1):162-73.

Objectives: The objective was to estimate the effect of a wide range of occupational psychological and social factors on subsequent neck pain intensity.

Methods: A prospective cohort study with a two year follow-up period was conducted with a diverse sample of Norwegian employees. Cross-sectional analyses were conducted at baseline (n = 4569) and follow-up (n = 4122). The number of employees eligible for prospective analyses (by completing the questionnaire at both time points) was 2419. Prospective analyses were conducted with the following types of predictors: (1) baseline exposure, (2) average exposure over time [(T1+T2)/2], and (3) measures of change in exposure from T1 to T2. Ordinal logistic regression models were conducted.

Results: Cross-sectional analyses ***at baseline*** exhibited statistically significant adjusted associations ($p<0.01$) of neck pain intensity with *quantitative demands, decision control, control over work intensity, role conflict, support from immediate superior, empowering leadership, fair leadership, predictability during the next month, commitment to organization, social climate,* and *working with arms raised to or above shoulder level*. Odds ratios ranged from 0.36 (*commitment to organization*) to 2.55 *(role conflict)*. Cross-sectional analyses ***at follow-up*** exhibited statistically significant adjusted associations ($p<0.01$) of neck pain intensity with *quantitative* *demands, decision demands, decision control, control over work intensity, role conflict, empowering leadership, fair leadership, predictability during the next month, commitment to organization, positive challenge,* and *working with arms raised to or above shoulder level*.

Adjusted ***prospective*** regressions showed that the following **baseline** exposures predicted neck pain intensity: *decision control, role conflict, empowering leadership,* and *positive challenge*. Odds ratios with p<0.01 ranged from 0.48 *(positive challenge)* to 2.97 (*role conflict*). The following factors predicted follow-up pain intensity when **exposure across time points was averaged:** *decision control*, *role conflict, role clarity*, *empowering leadership, fair leadership, predictability during the next month, commitment to organization,* and *working with arms raised to or above shoulder level.* Odds ratios ranged from 0.53 *(empowering leadership)* to 3.01 (*role clarity*). When categorized according to ***change in exposure*** *the following factors predicted neck pain intensity: decision control, role conflict, empowering leadership, social climate, physical workload,* and *working with arms raised*. Odds ratios ranged from 0.58 (repeated high *social climate*) to 2.16 (repeated high *role conflict*).

In order to separate ***etiologic*** factors from ***prognostic*** factors regressions were conducted separately among those reporting pain at baseline and those reporting no pain at baseline to predict *new onset* and *recovery from pain*, respectively. Among employees reporting no pain at baseline *empowering leadership* statistically significantly reduced the likelihood of reporting neck pain at follow-up (OR 0.83, p<0.01). Among employees that did report pain at baseline *role conflict* (OR 0.71, p<0.0007) and *commitment to organization* (OR 1.31, p<0.01) were statistically significant predictors of *recovery*, i.e. being pain free at follow-up.

Conclusions: The factors most ***consistently*** associated with higher neck pain intensity were *role conflict* (highest OR 2.97, 99% CI: 1.29-6.74) and *working with arms raised to or above shoulder level* (highest OR 1.37, 99% CI: 1.05-1.78). The most consistent protective factors were *empowering leadership* (lowest OR 0.53, 99% CI: 0.35-0.81) and *decision control* (lowest OR 0.60, 99% CI: 0.36-1.00). Although well known factors such as job demands and control may play a part in the etiology of neck pain, in this study several novel factors emerged as more reliable predictors of neck pain intensity. Furthermore, these factors were more specific than is often the case in comparable studies. This increases the potential for this knowledge to aid practical work to improve job conditions.

4.2. Paper II

Christensen JO, Knardahl S. Work and back pain: A prospective study of psychological, social, and mechanical predictors of back pain severity. European Journal of Pain 2012;16(6):921-33.

Objectives: To enhance current knowledge about psychological and social work factors of importance to employee health a comprehensive set of specific psychological/social and mechanical work factors were studied as predictors of back pain severity (defined as the product of back pain intensity and duration).

Methods: The sample comprised employees from 28 organizations in Norway who were surveyed twice with a two year follow-up period. Cross-sectional analyses were conducted at baseline and follow-up. Prospective analyses were conducted with: (1) baseline exposure, (2) average exposure over time [(T1+T2)/2], and (3) measures of change in exposure from T1 to T2. The baseline cross-sectional sample consisted of 5212 employees and the follow-up sample consisted of 4722 employees. A total of 2808 employees responded to both surveys. Odds ratios were computed by ordinal logistic regressions. Fourteen psychological/social and two mechanical exposures were studied.

Results: Cross-sectional analyses revealed associations of back pain severity ***at both baseline and follow-up*** for *quantitative demands, decision control, control over work intensity, role conflict, empowering leadership, fair leadership, predictability during the next month, job satisfaction,* and *physical workload*. Some factors were statistically significant at one time point only: *Decision demands, commitment to organization*, *positive challenge* and w*orking with arms raised* at ***baseline*** and *social climate* at ***follow-up***. Statistically significant odds ratios ranged from 0.73 (*job satisfaction* at follow-up) to 1.39 *(role conflict* at baseline).

Prospectively, **baseline** levels of *decision control, role conflict, empowering leadership, fair leadership,* and *physical workload* were predictive (p<0.01) of back pain severity at follow-up. Odd ratios ranged from 0.62 (level 4 of *empowering leadership)* to 1.74 (level 4 of *role conflict*). With **average exposure as predictor** statistically significant associations were observed for *decision control*, *role conflict, empowering leadership, fair leadership, predictability during the next month, job satisfaction* and *physical workload.* Odds ratios ranged from 0.41 (level 4 of *job satisfaction*) to 1.77 (level 4 of *role conflict*). When examining ***change in exposure*** as predictor, statistically significant associations were observed for *decision control, support from immediate superior, empowering leadership, fair leadership, predictability during the next month, social climate,* and *positive challenge*. Odds ratios ranged from 0.63 (constant high *positive challenge*) to 0.72 (decreased *support from immediate superior*).

Conclusions: After adjustment for age, sex, skill level, back pain severity at T1, and other exposure factors estimated to be potential confounders, the most consistent predictors were the protective factors *decision control* (lowest OR 0.68, 99% CI: 0.49-0.95)*, empowering leadership* (lowest OR 0.59, 99% CI: 0.38-0.91), and *fair leadership* (lowest OR 0.54, 99% CI: 0.34-0.87). Some of the most robust predictors of this study have previously received little attention in studies of musculoskeletal pain. This underscores the need of extending the list of occupational factors that possibly contribute to somatic pain.

4.3. Paper III

Christensen JO, Knardahl S. Work and headache: a prospective study of psychological, social, and mechanical predictors of headache severity. Pain 2012;153(10): 2119-32.

Objectives: The aim was to identify occupational psychological, social, and mechanical factors predictive of headache severity after two years. A full panel design was utilized to evaluate the tenability of competing causality hypotheses.

Methods: Data were obtained from two work environment surveys two years apart. A variety of organizations in Norway participated. The number of employees that participated at baseline was

6421 (“cross-sectional sample 1”), at follow-up 5930 (“cross-sectional sample 2”), and at both baseline and follow-up 3574 (“prospective sample”). Ordinal logistic regressions were carried out to obtain effect estimates. *Cross-lagged* and *synchronous* structural equation models were specified to test the tenability of different causal hypotheses.

Results: Adjusted ***cross-sectional*** regressions with continuous predictors at **baseline** revealed statistically significant ($p<0.01$) associations for *quantitative demands, decision demands, decision control, control over work intensity, role conflict, support from immediate superior, fair leadership, predictability during the next month, commitment to organization, job satisfaction,* and *working with arms raised to or above shoulder level* with headache severity. Odds ratios ranged from 0.76 (fair leadership) to 1.43 (role conflict). At **follow-up** *quantitative demands, decision demands, decision control, control over work intensity, role conflict, fair leadership, predictability during the next month, job satisfaction,* and *physical workload* were associated with headache severity ($p<0.01$). Odds ratios ranged from 0.67 (decision control) to 1.42 (role conflict).

Prospectively, more severe headache at follow-up was predicted ($p<0.01$) by higher **baseline** levels of *quantitative demands and role conflict,* and lower **baseline** levels of *decision control, control over work intensity* and *job satisfaction*. Assessing across time **averaged** exposure confirmed the same statistically significant predictors and furthermore higher *decision demands* and less *fair leadership* predicted more severe headache.

The most consistent predictors from the regression analyses were selected for further causal analysis. Hence, *quantitative demands, decision control, control over work intensity, role conflict*, and *job satisfaction* were analyzed in structural equation models specifying different causal structures (see the methods section above). All of these models revealed strong overall fit. For quantitative demands, control over work intensity, role conflict, and job satisfaction all RMSEA ranged 0.02 – 0.05, CFI ranged 0.99 – 1.00, and TLI ranged 0.98 – 1.00. The models involving *decision control* exhibited acceptable fit with an RMSEA of 0.07, a CFI of 0.96, and a TLI of 0.95 for all models.

The comparison of causal models was conducted by chi square difference tests. Thus, pairs of nested models were compared. Statistically significant chi square difference indicates that the more complex model adds significantly to the explanation of data. The following description is based on comparisons starting with the “stability models” (containing only autoregressions, i.e. T2 measures regressed on T1 measures of themselves) and then adding paths that increase the complexity of the model. For *quantitative demands* adding a “normal” regression path from quantitative demands T1 to headache severity T2 *did not* improve model fit. However, adding a “reverse” regression path from headache T1 to quantitative demands T2 *did* improve fit. The “reciprocal” model that included both the “normal” and “reverse” regression paths did not improve fit over the “reverse” causality model. Thus, across time the “reverse” causality model was most tenable. On the other hand, the *synchronous* models supported “normal” effects: Adding a “normal” regression path improved the model over the stability model, but adding a “reverse” path did not.

The *cross-lagged* models of *decision control* and *control over work intensity* exhibited similar results to each other. The “normal” regression paths *did* improve model fit over the stability model. Adding “reverse” effects did *not* improve fit. The full reciprocal model *did not* improve fit over the “normal” causality model. An identical pattern of results was observed for *synchronous* models of *control over work intensity,* supporting the “normal” causality assumption. For *decision control* the “reverse” effect path as well as the “normal” effect path improved fit over the stability model. However, adding a “reverse” path to the “normal” model to obtain a full reciprocal model did not improve fit. Moreover, adding a “normal” effect path to the “reverse” model did improve fit, thus indicating that the “normal” model was preferable.

For *role conflict* none of the added effect paths improved the fit of the *cross-lagged* model over the stability model. However, for the *synchronous* models all added effect paths improved the explanatory power of the model over the “stability” model. Adding “reverse” paths to the “normal” effects model did not improve fit, but adding a “normal” effect path to the “reverse” model did improve fit. Thus, also for role conflict the “normal” causality assumption was most tenable.

For *job satisfaction* all *cross-lagged* $\Delta\chi^2$-tests were significant, implying that the "reciprocal" causality model improved fit beyond both "normal" and "reverse" causality models. *Synchronous* models exhibited a non-significant change in chi-square when adding a "reverse" path to the "normal" model. This indicates that the "normal" causality assumption was most tenable when assessing synchronous effects.

Conclusions: The most consistent predictors of more severe headache were higher *quantitative demands* and *role conflict*, and lower *decision control*, *control over work intensity*, and *job satisfaction*. Cross-lagged models supported the notion that *decision control, control over work intensity*, and *job satisfaction* influenced later headache severity. A reverse influence of headache severity on the report of *quantitative demands* was indicated. For *role conflict* no effect across the two year follow-up period was detected. On the other hand, *synchronous models* indicated that each of these five exposure factors exerted an effect on headache severity over a shorter time span than the follow-up period.

4.4. Paper IV

Christensen JO, Knardahl S. Time-course of occupational psychological and social factors over time as predictors of new-onset and persistent neck pain: a three-wave prospective study over four years. Submitted manuscript.

Objectives: The study aimed to characterize exposure trajectories of a cohort of Norwegian employees (N=1250) over four years and to relate the levels of psychological and social work factors over time to the occurrence of neck pain.

Methods: Exposure information was collected at three time points two years apart. Group-based trajectory modeling (GBTM) characterized the development of exposure across time of five factors: *quantitative demands, decision control, social climate, empowering leadership,* and *role conflict*. The prevalences of neck pain in the different groups of employees characterized by different exposure developments were compared. Both risk and prognosis were elucidated by estimating the risk of neck pain at the third wave of the study among employees with and without neck pain at the first wave.

Results: The trajectory estimations supported a notion of stable levels of exposure across time for all factors. Groups were accordingly defined that reflected stable high, middle, and low levels for *quantitative demands, social climate, empowering leadership,* and *role conflict*. For *decision control* a four level classification was supported, designating stable high, high middle, low middle, and low levels over time.

Group differences in risk of neck pain at T3were observed for all factors after controlling for pain at time 1, skill level, sex, and age group. Statistically significant odds ratios obtained by logistic regressions ranged from 0.38 (CI 0.20-0.73, $p<0.01$) for high vs. low levels of *social climate* to 3.00 (CI 1.63-5.50, $p<0.01$) for high vs. low levels of *role conflict.* Subsequently, the sample was divided into two groups based on pain status at baseline.

For subjects reporting *no pain at baseline*, the risk of new-onset neck pain during the follow-up period was influenced by all factors, with ORs ranging from 0.32 (CI 0.16-0.67, $p<0.01$) for high vs. low levels of *empowering leadership* to 2.61 (CI 1.09-6.21, $p<0.05$) for high vs. low levels of *role conflict.*

For subjects reporting *pain at baseline,* the risk of persistence at T3 was influenced by high vs. low levels of *role conflict* (OR 3.26, CI 1.30-8.18, $p<0.05$), high vs. middle levels of *quantitative demands* (OR 3.66, CI 1.58-8.49, $p<0.01$), and high middle vs. low middle levels of *decision control* (OR 0.45, CI 0.21-0.99, $p<0.05$).

Conclusions: Different levels of psychological and social work factors over four years predicted occurrence of neck pain at the end of the study period. This was the case both for employees with and without neck pain at the beginning of the study. Future studies should collect more information about exposure over time to clarify the impact of different levels and developments of working conditions on musculoskeletal health complaints.

5. Discussion

5.1. Main contributions of the current studies

Among the most important features of the works presented herein is the comprehensive coverage of a large domain of psychological and social aspects of occupational activities. This has not been common in previous research pertaining to somatic pain. It allowed the evaluation of the relative importance of a great number of factors, many of which have previously received little attention in this research field. At the most general level, the results lend support to the notion that psychological and social work exposures can cause or influence somatic health afflictions. Most factors were associated with health complaints (i.e. neck pain, back pain, and headache) in some way. Due to the large number of factors involved, a fairly strict approach was chosen: criteria for conclusions regarding associations with pain were that factors were consistently statistically significant across analyses, after adjustment for possible confounders, and with a confidence limit of $p<0.01$. From this a limited number of factors emerged as consistent predictors. Perhaps most interestingly, some factors that have dominated previous research questions did not seem to dominate the current results when studied alongside many other factors. Overall, the most consistent predictors across studies were the protective factor *decision control,* which was a statistically significant predictor in all conducted analyses for all three health complaints, and the risk factor *role conflict*, which was a statistically significant risk factor in all analyses except one analysis pertaining to back pain (the "exposure change variable"). While decision control is a well known protective factor for musculoskeletal pain, role conflict has rarely been studied as a separate, specific factor. It is often considered a "Job demand", but in the current studies it appeared to operate quite independently of other types of demands. While *quantitative demands* was predictive only of headache (with indications of reverse causality across time), *decision demands* were consistently unrelated to the studied health parameters.

Other indications of the impact of fairly novel factors also appeared. *Empowering leadership* was a consistent predictor of neck- and back pain in study I and study II. The significance of empowerment may be underappreciated in previous research. The role of adequate opportunities for self-management may be crucial in unspecific health complaints in order to prevent perceptions of hopelessness, helplessness, and exacerbation. Also, the psychological significance of perceiving leadership as facilitative may play a part in enhancing positive appraisals and reducing alarmist cognitions by inducing positive and relaxed moods. Such mechanisms could also be involved in the positive effects of *fair leadership*, which was a consistent predictor of less severe *back* pain. Behavioral mechanisms could also be speculated to underlie the consistent associations between *control over work intensity* and headache that were observed in study III. For instance, lacking control of the pacing of work may prevent employees from taking necessary breaks and instead motivate exaggerated self-medication as a coping strategy. Thus, control over work intensity may contribute to medication overuse headache (MOH) (Diener & Limmroth, 2004).

Job satisfaction was also a consistent predictor of headache. While this is interesting, the previous discussions have also made it clear that the global concept of job satisfaction is problematic. In itself it does not inform of specific work factors that may be modified to enhance employee health. Also, the measure was skewed, indicating that most employees were satisfied. This is often the case with measures of satisfaction, and it may mean that they are only sensitive on the negative side, implying that what can be said about the effect of satisfaction on health mostly pertains to the obvious cases of dissatisfaction. One could speculate that reports of strong dissatisfaction are more likely to be influenced by trait negative affectivity as well as negative life circumstances. Hence, more information about work exposures that influence job satisfaction is needed, both in order to make focused work improvement interventions possible and to elucidate the role of reporting tendencies in the satisfaction-health relationship.

Importantly, *quantitative demands* appeared to be of less significance than what may have been expected from previous research. In fact, studies III and IV did suggest a role for this factor, but in ways that may perhaps not have been elucidated in many studies before. There may be a fundamental difference in the ways in which different types of demands influence the subjective experience of somatic health. Importantly, future research should not only separate specific components of demands, but also evaluate the differential impact of the time-course for these different aspects of job demands. While some demands may not be the most important influences on health in the short term, negative consequences could manifest after prolonged periods of exposure.

It has been pointed out that inconsistent and unspecific findings of previous research may indicate that no real association exists, but that findings arose in some studies by chance ("false positives"/type 1 error) (Hartvigsen et al., 2004). Although it may be reasonable to suspect that some factors become statistically significant in this way, the current results suggested the need to acknowledge that inconsistency may also result from the *opposite*; namely a *failure* to detect exposure-health associations that actually exist ("false negatives"/type II error). One source of such detection failure may be conceptually confounded exposure factors. The current studies emphasized the importance of specific factors in order to disentangle the impact of different aspects of work. Thus, general factors such as job control and demands were represented by some of their more specific aspects (e.g. control over work intensity vs. decisions). The investigation of these more specific factors suggested that the more general concepts may comprise sub-dimensions that are differentially related to the health outcomes under study. Thus, many previous studies may have failed to detect associations due to the conflation of these aspects. For example, study I suggested that role conflict, but not quantitative demands, was an important independent predictor of neck pain intensity. Both these factors represent aspects of "job demands" as it is commonly operationalized. Furthermore, study IV suggested that quantitative demands may indeed cause neck pain, but in a different way than role conflict. Possibly, role conflict has a more immediate impact whereas quantitative burdens affect health in the longer run. The consequence of this could potentially be that combining these factors into one exposure measure may affect results and hinder detection of effects. Furthermore, since quantitative demands exhibited a curvilinear effect on neck pain (i.e. both high and low demands over time were adverse, see study IV), the common practice of dichotomization can lead to severe misclassification and thus mask important effects by mixing "exposed" and "non-exposed" individuals. Moreover, since role conflict and quantitative demands are not necessarily highly correlated (de Araujo & Karasek, 2008) a high score on a scale that combines them could sometimes represent risk and sometimes not, depending on which sub-dimension is high (and for how long it has endured). Similar differential relevance was observed for other factors as well.

These concerns could represent a partial explanation for the lack of specificity of previous research results.

Not only may some factors be more relevant than others to different health complaints, but the way in which they influence health (i.e. pathogenic pathways, required exposure duration, threshold effects, and so on) may vary. Naturally, risk factors will not be detected as statistically significant if they influence health in ways that are not appropriately reflected by the designs and analyses of a study. Another important contribution of the current works was therefore the indication that ignoring exposure development and duration may affect the power of studies to detect effects. Stronger and more reliable associations were observed with repeated-exposure information than when employing the more common strategy of predicting pain from baseline measures of exposure. This was particularly evident in study IV, which assessed the association of exposure profiles over three time points on both risk and prognosis of neck pain. Also, the exposure classification of study IV did not use arbitrary cut points to determine the different levels of exposure to classify by, but determined these by identifying clusters of similar exposure profiles between subjects. This may suggest that inconsistencies in and between previous studies may be partially attributable to arbitrary classification of exposure and a failure to incorporate information from multiple time points. Classification is particularly difficult since different exposures may require different time courses as well as levels to exert an effect. It is therefore important to clarify potential differences in the pathogenetic relevance and –mechanisms of different psychological and social work factors so that studies may more efficiently model the exposure-health relationship. The current results exhibited some patterns that may call for a change in the way the typical study is designed, analyzed, and interpreted. Most importantly, single time point estimates of exposure should be employed with caution and efforts to clarify the development of exposure should be made.

In order to compare the current results with previous research and provide a context within which to interpret the results, the current thesis has often referred to the Job strain model. This model remains dominant in this field of research. Hence, criticisms of the current works are not so much a response to the Job strain model *in itself* as a criticism of the overreliance on one particular general theoretical model in guiding research. Also, the possible problems noted in the current studies pertain to a large degree to the way in which the common measurement instrument (the JCQ (Karasek et al., 1998)) is constructed, i.e. the lack of discrimination between specific aspects of general factors, rather than the theory it was operationalized to test.

Kristensen (1995) has summarized some concerns regarding the Job strain model (Kristensen, 1995), many of which resonate with how the current research relates to previous research. Among the concerns Kristensen expressed regarding the Job strain model the following were consistent with the findings of the current studies: (1) The model is too general and unspecific. More than a few broad dimensions are needed to discover health impacts of psychological working conditions. Moreover, the decision latitude dimension in particular consists of two sub-dimensions that are not necessarily correlated. (2) Associations may be different for different health complaints; it may be too general to claim that a demand-control imbalance is unfavorable to health. (3) There may be curvilinear effects, with middle levels of exposure being optimal. In conclusion, the current studies have provided information that may be useful in guiding the further attainment of knowledge. Most importantly, the research field may benefit substantially from studying additional factors that are more specific and it may be necessary to separate qualitative and quantitative aspects of job demands (this has also been suggested by e.g. (de Araujo & Karasek, 2008)). Also, collecting information about both exposure and health from multiple time points and actively incorporating it in analytic strategies may be helpful in order to reveal consequences of different courses of exposure.

5.2. Strength of associations

When assessing evidence of the link between psychological work factors and musculoskeletal pain some authors have classified odds ratios between 1.00 and 2.00 as moderate association, and odds ratios above 2.00 as strong associations (Hartvigsen et al., 2004). According to this, many of the associations observed in the current studies would not be labeled strong. However, causal relationships do not necessarily produce strong associations. It is clear that the etiology of regional musculoskeletal pain is complex and that many sources of influence determine the degree of experienced pain. It has been convincingly argued that the relationship of specific psychological and social work factors with health cannot be assumed to be strong since health is multifactorial and influenced by a wide array of work- and non-work factors (Zapf et al., 1996; Semmer et al., 1996). The “upper limit” that can be expected for estimates of association of single stressors with strain and well being has been suggested to be equivalent of a correlation of 0.30 (Semmer et al., 1996). Moreover, the validity of exposure measures can rarely be assumed to be 100 %, and the strength of an influence often depends on moderating influences, such as healthy worker effects. Also, the within-subject variability in pain reports over time may be considerable (Steingrimsdottir et al., 2004), which may also influence exposure-outcome associations by affecting the reliability of pain measures obtained at single time points. Hence, the observed associations of the current studies seem realistic.

Naturally, the degree of complexity of a psychological work environment is difficult to elucidate. Consequently, it is hard to gain an overview of possible moderators that may have influenced the studied associations. Not only may it be expected that the direct effect of exposures on pain may be moderated by other factors present in the work situation. Also, the effect of the exposure on the mediator can be moderated. For instance, one pathway may go through emotional responses to working conditions. Imaging studies have shown that induction of depressed mood can alter pain processing in the brain (Berna et al., 2010). Thus, if adverse working conditions induce depression this may be one mechanism by which they influence pain. However, a number of other factors may influence the severity of depression as well, or moderate the effect of work on mental health to make it more or less pronounced. For instance, some individuals may be more prone to depressive reactions to adverse conditions. This could in turn affect the degree to which work influences pain in subgroups of individuals with different characteristics. Similarly, physical fitness may determine the extent of fear-avoidance behaviors and the level of physical activity which in turn may influence the severity of work-related depression as well as having a direct effect on pain. All of this is the potential subject of future investigation, but it makes the general point that the association of specific work factors in isolation with health cannot necessarily be expected to be too strong or specific, particularly when experimental control over all other factors is impossible. Also, studies often appear to put more emphasis on causal *inference* than estimation of causal *strength.* The adjustment for a variety of hypothetical confounders as well as previous levels of the health complaint will often diminish effect estimates.

It may also be noted that causal strength is not always the best measure of the potential to reduce or prevent ill health. While many other exposures may be more directly related to pain occurrence and severity, few are as modifiable on a large scale as specific work factors. Working conditions are relevant to so many who are or will be afflicted by pain problems. It is important to note that if non-tangible work aspects influence several other factors that may influence pain, such as health behaviors, sleep quality, or depression and anxiety, then successful interventions targeting these work factors may have a stronger impact than less successful attempts to directly intervene to modify these mediating factors.

5.3. Different aspects of pain

The measures of pain complaints employed in the current studies did not separate affective and sensory-discriminative aspects of pain. Furthermore, it is possible that some employees interpreted the questions to be about any form of uncomfortable somatic sensation, so that e.g. discomfort, paresthesia, or muscular tension were encompassed by the outcome variables. While it seems unlikely to have been the case for most respondents, especially since the observed prevalences were comparable to previous pain studies, further studies that distinguish between different aspects of pain could be informative and provide relevant information about the nature of the work-pain relationship. Nevertheless, although general outcome measures may dilute effect estimates, from a practical viewpoint it may be relevant to encompass a range of outcomes although they are in principle distinguishable if they are all important to function and disability.

Since there are a variety of plausible biopsychosocial pathways to pain, different aspects of pain may be affected in different ways by different factors. According to some models pain conditions may arise as a result of prolonged psychological adversity due to interference with the regulation of inflammatory activity in the body (Mcewen & Stellar, 1993). On the other hand, studies of the *nocebo response* often involve cognitively mediated hyperalgesia as an added impact on stimuli that are also painful when nocebo is absent (Benedetti et al., 2007). Thus, both the *onset* of pain and the *severity* of pain may be influenced by psychological factors. However, different psychological factors may mediate these different effects. Further complicating the problem, the *same* factors may influence *different* aspects of pain at *different* stages of exposure development over time. That is, a work exposure may influence pre-existing pain by way of altered pain-related cognitions in the short term *and* induce the onset of pain in the long run by influencing hormonal excretion patterns. More detailed pain measures may add valuable information about this possibly complex pattern of differential influences of different factors and differential influences of aspects of the same factors. Moreover, not only the onset vs. intensity discrimination is of possible relevance. Psychological factors have the potential to modulate *intensity* as well as *unpleasantness* of pain (Eisenberger & Lieberman, 2005) and they can affect these aspects separately, as when intensity is modulated without altering unpleasantness (Grahek & Dennett, 2007). In such cases subjects report increased pain but are not bothered by it, demonstrating that the distinction between the sensory-discriminative and affective-motivational dimensions is not merely analytical. Thus, it is possible that different factors may influence intensity and unpleasantness to different degrees. Although elucidation of these concerns remained outside the scope of the current research, the degree to which psychological work exposures influence separate aspects of pain should be investigated.

5.4. Differential impacts

The possibility of *chance* findings cannot be ruled out in the current studies due to the comprehensive set of factors that was examined. One main aim was to broaden the scope and explore a large number of exposures. While this may be important in order to uncover the differential impact of different exposures with different psychological content, it also inflates the risk of observing statistical significance by chance. A relatively strict approach was therefore taken, with adjustment for multiple testing and inclusion of “confounders” that may actually be substantive factors in the pathogenesis of the respective health complaints. Nevertheless, caution must be taken when interpreting results. Although it seems unlikely that all findings are spurious, given the consistency of results when judging not only statistical significance but direction of effects, replication of the current results in different samples is necessary. However, it may be noted that the practice of publishing multiple studies examining a few factors at a time is not less prone to capitalizing on chance if data are derived from the same data pool. In fact, one could suspect that such strategies to a larger extent capitalize on chance and contribute to publication bias by not selecting for further study factors that seem less important in preliminary analyses. Also, p-values may often not be appropriately adjusted for multiple testing since each separate publication does not appear to test multiple factors.

The problem of multiple testing also affects the interpretation of which factors emerged as significant *between* the studies of different somatic regions. In other words, it is not necessarily straightforward to judge whether there are differential impacts of the exposures on the different regions of the body (i.e. neck, back, and head). The health complaints investigated in the current thesis were interrelated. This is to be expected since pain presenting in multiple regions of the body has been reported to be more common than single site pain (Carnes et al., 2007). Cross-sectional bivariate Spearman correlations of intensities of the different complaints at baseline in the sample of study III were 0.42, $p<0.01$ (headache with neck pain), 0.24, $p<0.01$ (headache with back pain), and 0.33, $p<0.01$ (back pain with neck pain) (analyses not shown). This adds further inclarity to the question of whether the predictions of pain by the factors of the current studies represented effects specific to the regions investigated. There may be a part of this impact that is complaint-specific (i.e. an effect on pain in a specific region) and a part that is complaint-independent (i.e. an effect on “any” pain, or pain “per se”). An exploration of this is beyond the scope of the current work, but the notion is both theoretically and practically relevant. Hypothetically, it could be that some factors have a great impact on the “common component” of these different health complaints while other factors have effects only on specific complaints, perhaps through influencing activity patterns that determine biomechanical loads of specific somatic sites. Further investigations may for instance consider the distinction between a higher order latent pain factor, identified as the common variance of different complaints, and the unique variance associated with each separate complaint, in order to distinguish between possibly differential impacts of exposures on “general” and “specific” pain components.

5.5. Methodological considerations

5.5.1. Concerns regarding self-report methodology

As discussed previously, concerns are often expressed regarding the potential pitfalls of self-report and particularly the reliance on it to assess all variables of a study. The main contribution of the current works in this respect is to employ exposure measures that have been properly defined and validated, where many previous studies have relied on unspecific ad hoc instruments (often referring to "stress"). However, the present studies are not unaffected by concerns associated with self-report. There are a number of ways in which employees may, knowingly or unknowingly, misrepresent their working conditions when asked to report them. Some of these will inflate and others will deflate associations.

Recall bias may result if subjects substitute incomplete memories of complex situations with more easily available *heuristics* (a process named *attribute substitution* (Kahneman & Frederick, 2002)). For example, rather than thinking back in order to form an adequate, representative reflection of the general working situation, employees may assume that current conditions are valid representations of the past. This bias should increase with the degree of fluctuations of working conditions and the length of the period that information pertains to. Another way in which recall may be biased is if single salient events of the past period dominate the employee's general perception of conditions at work. These events may in fact be isolated, rare events. They could, however, be psychologically significant. Thus, whether or not this "over-report" is a bias is not unambiguous. When health is affected through cognitive and emotional mechanisms this selective "misrepresentation" may not be an obvious bias but may describe one way in which certain work factors may influence health (i.e. by "hijacking" cognitive-emotional processing). However, in such cases it may not be unproblematic to ascertain that a modifiable exposure caused ill health since the strength of the effect does not depend on the *frequency* of the stimuli but rather the saliency of it. In other words, "strain" may not occur due to *frequent* role conflicts (for instance) but one single occurrence of role conflict may dominate the perception of the employee. Consequently, this employee may report that the work situation is characterized by role conflicts despite this not being apparent to others.

Strategic misinformation could occur if employees deliberately misrepresent working conditions because they fear the consequences of being honest or think that they have something to gain from not being honest. Coerced compliance could induce systematic error if employees give overly positive assessments in order to avoid reprimand. On the other hand, if employees do not feel intimidated by consequences of what they report, overly *negative* assessments could be induced by discontent from feelings of being forced to participate. Naturally, these potential sources of error presuppose that one is measuring something which employees can clearly rate on a bipolar scale ranging from negative to positive, whether this is the explicit scale scoring or the implicit assumptions of the employees about the endpoints of the scale.

When considering these possible errors of self-report one should perhaps distinguish between assessments of the general, “objective”, work *environment* and factors related to or encompassed by it. Concerns about reporting bias often seem to regard alleged biases generated by questionnaire assessment when attempting to estimate the characteristics of the work *environment* (i.e. the environment in which employees are situated). Thus, perhaps some “pseudo”-disagreement has resulted from a failure to clarify what level these factors should be assumed to operate on. Karasek originally intended the Job strain model to reflect an objective sociological reality and asserted that "it presumes existence of socially "objective" environments that systematically affect individual well-being and behavior" (Karasek, 1979, p. 326). The current research did not make assumptions about this "objective" entity abstraction. Rather, what were being measured were aspects of work that reside in the subjects’ perceived reality. This is not meant to estimate the actual reality of a uniform “psychosocial environment” as if it exists independently of the individuals that create, perceive, and are affected by it. Employees were assumed to interpret and appraise their environments and jobs in order to evaluate and align them with personal standards and needs and the outcome of this process is the evaluation of work. For example, it seems inappropriate to take self-report of “positive challenge” to be an estimate of an inherent characteristic of working conditions independent of individual motivational contingencies. It is not an independent attribute of the work environment, but rather an aspect of work that is defined by the relationship between external demands and individual attributes (e.g. preferences, personal goals, fears). The individual appraisal of environmental demands determines whether they are "positively challenging" or "threatening" and this appraisal may determine the effect on psychological and somatic health.

Naturally, if one is interested in the objective characteristics of work, the validity of self-report must be judged in a fundamentally different way. It is then a question of the accuracy with which workers can perceive and convey external conditions as well as how accurately the measurement instrument captures this information. With regards to measurement methods that have often been referred to as "objective", such as ratings by independent observers or supervisors, one should not automatically assume that they are less error-prone than self-reports (Semmer et al., 1996). "Objective measures", which should not be viewed as a single uniform type of measurement method, are not unbiased but exhibit their own biases, some of which are similar to those of self-assessment since perceptual biases and individual judgments are involved. The problem is especially pronounced when concepts are not unambiguously objective by nature. Thus, although "objective" measurement should be undertaken it should perhaps not be entered into competition with "subjective" measurement as they may pertain to fundamentally different domains. Some "job demands" may be conceptualized as unambiguous, quantifiable characteristics of tasks. Their impact on health may go through the psychological *consequence* of, for instance, an increased number of tasks per time unit. In this case demands are defined independently of the psychological consequences that may mediate their effect. However, some demands are psychologically *defined* as well. Such demands may be less suitable for objective operationalization since they encompass a wide range of conditions that have the same psychological significance but no general, intrinsic content (e.g. no specific range of measurable behaviors can be said to constitute the concept). Role conflict, for instance, is among other things the incongruence between tasks that must be executed according to a job description and tasks that are imperative to the individual. Objective assessment of this is complicated since personal values are involved. Self-report allows the subject to communicate a qualified judgment that is relevant. It seems hard to conceive of any "objective" way to determine the incongruence between external demands and personal values, unless one restricts measurement to specific occurrences of examples of role conflict. However, this may result in poor coverage of the different ways in which role conflicts may manifest.

As previously suggested, one of the central caveats which concerns self-report bias is the possibility that observed associations are spurious due to the clustering of certain types of responses in certain types of individuals. The co-measurement of exposure and outcome with the same method may thus produce spurious correlations. Employees experiencing negative affect (due to personal dispositions or the context of the questionnaire completion) may report adverse working conditions and ill health in tandem and those with optimistic inclinations may ignore problematic working conditions as well as symptoms of health problems. However, the subjective nature of emotions may be relevant to the research topic. Subjects with an affinity for negative or anxious interpretation of work events may be more vulnerable to what happens at work. That does not, however, automatically disqualify their perception of working conditions and should not in itself invoke the label of "bias". Personality traits are not defined independently of situational characteristics, but rather in *relation* to them. Individual dispositions may affect how situations are perceived and responded to and these responses may influence the situations (Buss, 1977; Larsen & Buss, 2005). "Objective" observation or *aggregated* measurement, e.g. at the departmental level, may be criticized for being biased due to *not* being sensitive enough to individual variation occurring within a work environment. It may be that the individuals that are “adjusted for” are the ones most adequately equipped to detect “warning signals” about characteristics of work that are relevant to the well-being and health of employees. In addition, individual deviations from the common experience of work may be important since jobs may vary within units, and social environments may be heterogeneous within departments. Therefore, although apparently a democratic approach, aggregation may also run the risk of disregarding the concerns of minorities. These minority concerns may in turn be of importance to the majority. If one is interested in finding out whether associations between individual perceptions of working conditions (the "subjective" environment) and reports of ill health are spurious, strategies such as aggregation and “objective” measures may provide helpful and additional information, but they should not automatically be assumed superior to individual self-report although they convey a different kind of information.

In conclusion, individual predispositions to think in a negative or positive manner may cause individuals to pay selective attention to ambiguous (but affect-laden) stimuli that may be interpreted as a threat to health and well-being. This may cause a co-occurrence of certain types of responses, such as negatively appraised working conditions and suboptimal health. Although negative appraisal of work may *cause* suboptimal health, this co-occurrence may also in theory be completely spurious. If so, it does not provide practical information about the relationship between work and health. However, the QPS_{Nordic} is constructed to minimize such bias (e.g. neutral wording, items reflecting frequency of occurrence rather than agreement). Naturally, this does not and should not inoculate against the influence of the employee's private view of things, but it should alleviate concerns about self-report bias due to automatically induced emotional valence. Many previous studies have measured work factors by inquiring about "satisfaction" or "stress", making it more difficult to assume that the subject is reporting their working conditions rather than their own general discontent with life and health. The current surveys were conducted with the aim of avoiding focus on particular factors prior to the survey, so most respondents should have no particular reason to perceive particular questions as indicators of threat. It was carefully communicated that few of the measured factors are to be viewed as inherently negative or positive, and items with emotive content were purposely avoided. The fact that results differed for different factors and health complaints indicated that respondents did in fact meaningfully distinguish between factors based on a substantive consideration of items.

5.5.2. Over adjustment

There are many potential sources of over adjustment in the current studies. Adjustment for previous health complaints may partial out the effect of previous work exposures on health. Given the considerable stability of both exposures and effects, this diminishes power to detect effects and may result in underestimation. Also, data-driven confounder selection or "routine adjustment" of "conventional confounder variables" may lead to adjusting for intervening factors (mediators) or antecedents. Even such factors as skill level may be important substantive factors rather than nuisance factors to be partialed out. It is possible that social inequality of health stems partly from unequal working conditions (Marmot, Ryff, Bumpass, Shipley, & Marks, 1997). Similarly, skill level could be related to psychological working conditions so that employees with higher skill enjoy better working conditions and consequently have better health. High skill level was in the current studies associated with better health. If in fact certain work factors mediate the impact of skill level on musculoskeletal health the adjustment for skill level may be considered over adjustment.

The confounder selection procedure of studies I-III may be most vulnerable to criticism. Such procedures may effectively rule out the confounding influence of true confounders so that the resulting effect estimates can be considered robust. However, as was discussed in the separate studies, the procedure is blind to substantive concerns about the included factors. When dealing with an array of factors the procedure may be useful since confounding becomes a less likely concern. Thus, factors that emerge as robust can with greater confidence be interpreted as independent influences on the respective outcomes. However, the most severe drawback of this strategy is that it in many cases must be assumed to motivate type II conclusions. It does seem likely, for instance, that a factor such as social climate, which exhibited no statistically significant effects in studies I-III after confounder adjustment, is involved in a substantive causal dynamic with the factors for which it was adjusted, such as commitment to organization. Organizational commitment may be a result of a positive social climate or may share a precursor with social climate. Quality of supervision, which is a second-order factor comprised of empowering leadership, fair leadership, and support from superior, may be a determinant of both social climate and organizational commitment (Dallner et al., 2000). Thus, they may share variance not due to confounding but due to a common cause. If so, the lack of statistically significant *unique* explained variance in an outcome does not necessarily imply that both factors are not important in practice. In study IV social climate was indeed found to predict the occurrence of neck pain when assessed over a four year period and not adjusted for commitment.

5.5.3. Selection bias

Selection bias may have occurred if the study samples differed in relevant ways from the theoretical population to which results were inferred. Selection may occur at many stages, e.g. by determining who are members of the workforce at any given point or throughout a time period, which companies participated, and which employees within these companies that decided to actively participate. A number of unknown characteristics of companies and employees could have influenced the probability of response. Thus, as long as a random sampling procedure was not used to obtain data from a known population of eligible subjects, misrepresentation of the estimated exposure-health associations cannot be definitively ruled out.

Some indications of selective non-response based on studied factors were found. For instance, employees with higher decision control were more likely to be included in study IV. Although all companies agreed to allow employees time to complete the questionnaire, one could speculate that employees with higher decision control had more opportunity to structure their working day to prioritize this task. This selection effect may cause a problem of *external validity.* The severity of the problem depends on the degree to which a theoretical "high control" population differs from other populations with respect to the observed associations. To the degree that such (hypothetical) selection mechanisms affected external validity, estimates of causal effects are valid, but only for a population with equivalent characteristics to the studied sample. In the case of decision control one possibility could be that observed effects *depend* on a high level of decision control. Further studies can specify conditions that modify the strength of such relationships. One similar and often cited selection bias that may affect the size of the estimated work-health association is the *healthy worker bias* (Li & Sung, 1999). Employees experiencing adverse working conditions could drop out as a consequence of this and thus effects may be harder to detect. Study IV did provide some interesting indications of healthy worker selection in that the observed effects of exposures were generally stronger for employees that had been employed for less than the sample median number of years employed. This could indicate that employees with a long history in the same job are a selected group that is less sensitive to adverse effects of exposure.

Perhaps less commonly (although, arguably, more importantly) discussed than external validity is the possibility that selective response may affect *internal validity,* i.e. the degree to which observed associations stem from causal processes at all or are merely statistical artifacts (Hernan, Hernandez-Diaz, & Robins, 2004). Importantly, this requires that selection is based on both exposure and outcome. For instance, some individuals could avoid participation in the study because of poor working conditions, causing poor conditions to be underrepresented, but this would not in itself distort estimated effects of poor working conditions. The proportion of individuals with poor health would remain the same among those with poor working conditions.

Consequently, the ratio of the risk for employees with poor working conditions to the risk for employees with better working conditions would remain the same. If, however, selection were to be based on both poor working conditions and poor health, independently of each other, this could induce a completely spurious association since observing one would affect the probability of observing the other (Hernan et al., 2004). For instance, if employees in a sample report high control and poor health compared to the population, but control and health are unrelated, a person that reports high control would be less likely to report poor health.

It is often assumed that higher response rates indicate higher generalizability and less selection bias. By some standards, the response rates of the current studies were not particularly high. Systematic reviews often define response rates of 70% or 80% as markers of "high quality" (see e.g. (da Costa & Vieira, 2010a; Hartvigsen et al., 2004)). While it is true that low response rates could reflect relevant self-selection, it should be noted that this is not automatically the case, and that high response rates could also be caused by potentially biasing self-selection. One could suspect that external motivation factors such as coerced compliance or contingent rewards could be more effective in persuading employees to complete forms than to be truthful and accurate when doing so. The assumption that high response rates give more representative results has been challenged. For instance, one study of election forecasting by mail surveys showed that the most predictive surveys had the lowest response rates (Visser, Krosnick, Marquette, & Curtin, 1996). Also, a recent Danish population-based study compared estimates of risk of mental health outcomes derived from participants of a study with a 45 % response rate at baseline with the population risk estimates derived from national registries (Kaerlev et al., 2011). They found no evidence of an impact of a low baseline response rate on estimated *associations* between job strain and mental health even though there was selection by sex, age, employment status, sick leave, and hospitalization for affective disorders.

Thus, when assessing the importance of response rates it may be more relevant to consider possible reasons for attendance or non-attendance than mechanically applying quantitative criteria of quality. It is not merely a question of attaining information from as many units as possible to ensure representativeness of a more general population – if most respondents did not return valid information a high response rate would not remove the bias. The main question is perhaps not what proportion of invited subjects chose to respond, but why they did so. Some possible reasons of non-attendance in the current samples are discussed in the individual studies. As is necessary in research studies of this kind, participation was voluntary, informed, and anonymous, possibly leaving much room for different individual and group-level motivational processes to determine response. The questionnaire of the current studies was comprehensive, and it remains plausible that one important reason not to complete the form could be the time and effort required for this task. One concern that participants commonly communicated was that the form was long and time-consuming to complete. It also appeared that the response rate declined gradually throughout the form, indicating that there was little specific selection based on item content. As previously mentioned there was no specific focus on health issues in the presentations of the survey, and the communication of study aims prior to administration of the forms was general. The surveys were carried out with the aim of monitoring as well as improving working conditions, but with no particular focus on specific factors contained in the questionnaire.

5.6. Suggestions for further research

The current studies shed light on the association between work and pain, substantiated the causal hypothesis of psychological work factors and pain, as well as elucidated the role of a range of specific factors that should be suitable targets for practical intervention efforts to reduce the burden of current and future pain complaints and disorders in the currently employed workers. Some previously under-researched factors were elucidated that may play an important role in sustaining favorable health. It seems justified to encourage further studies to continue to broaden the scope by adding more factors to the list of candidate predictors. There may be many more relatively specific psychological factors that are important to worker health. Also, due to the number of factors examined and the non-random sampling, replication of the current results is necessary to clarify which factors are important predictors of health and under which circumstances.

Many plausible explanations have been formulated to explain the general link between perceptions of work and somatic health. Nevertheless, or perhaps because of the multitude of possibilities, it remains unclear why the identified predictors seemed to have an impact. A natural next step would therefore be to evaluate different possible hypotheses of pathways that can explain these associations. For instance, the role of psychological work exposures in modifying illness behavior as well as health-related cognitions and affect are interesting themes for further research. The interactions between work factors are also highly important to study, since no employee can be expected to be exposed to one exposure at a time. Importantly, the commonly employed models in this field of research have been centered on this premise. However, many research efforts have treated this notion rather superficially. With regards to the factors examined in the current studies it would be useful to further examine the potential of specific exposures to strengthen or weaken the effects of other exposures.

Investigation of personal characteristics as effect modifiers is also important to determine individual vulnerability or robustness. Moreover, including personality dispositions in models of exposure-health relationships provides an opportunity to evaluate whether the threat of reporting bias is an important part of the explanation. Certain traits may influence reporting of exposure and health to induce spurious association but it seems equally interesting to test the possibility that employees with a tendency towards negative emotion are more sensitive to working conditions that can also induce ill health in those with an affinity for positive thinking. A further question pertaining to the conditions under which work may affect health is the question of "exposure configurations". Since the effect of any one exposure may be moderate (perhaps depending on the duration of exposure) examining the net impact of different configurations of exposures may provide very interesting and more realistic estimates of the impact of psychological working conditions on health. This notion is not uncommon in previous research, since many studies have examined configurations of demand and control and support, but expansions may be warranted since it seems like many other factors are relevant. This should perhaps not be limited to a question of statistical interaction, but also of estimating typical configurations of exposure and their effects across and over time to realistically depict the consequences of work on health. Such research could be valuable in determining the actual "psychological load" employees are exposed to, and whether the accumulation of risk factors has additive or synergistic effects on the health of those employees that are exposed.

The effects in the current studies were demonstrated on a very general level, across all types of jobs, organizations, personality dispositions, et cetera. Given the aim of examining a large number of factors in studies I-III to identify predictors, model complexity was minimized. It was outside the scope of the studies to carry out detailed examination of these effects across companies or types of jobs. It would, however, be interesting to explore the possible variation of effects across different possible units of aggregation. For instance, multilevel modeling that explicitly takes into account different possible levels of clustering would have the potential to inform about the variance of effects over e.g. departments, organizations, geographical regions, job types, and so on. It is conceivable that different factors may have different effects at different levels of aggregation, and it seems especially relevant when studying factors that pertain to the social "environment" as opposed to those who pertain to individual job content.

5.7. Conclusions

The current thesis encompasses results that suggest the need for a more widespread use of additional study instruments in future research to complement research that focuses on a few common models. The current studies highlighted the role of some factors that have been relatively rare in previous research but that appeared more useful in predicting variation in important health problems in the current studies than more established factors. Thus, many exposure factors that have not been sufficiently researched to be included in systematic reviews need more elucidation. Although replication and further study is necessary to clarify if, why, and how the factors of the current studies are causally related to somatic pain, these investigations provide convincing reasons to elaborate the list of putative risk- and protective factors.

Some of the current factors may to a certain extent have been included in many previous studies, but as components of broader concepts such as "demands" or "control". The current results suggest the utility of defining more specific concepts due to possible differential impacts of aspects of what has often been operationalized as broad separate factors. There may be a difference in how discernible psychological concepts relate to different indicators of health since mechanisms may vary. Although work may affect health, many different aspects of work may affect health in different ways. Analogously, psychological factors such as demands and control may influence health, but specific aspects of them may need disentangling in order to attain specific knowledge about the influence of psychological working conditions on different aspects of health.

The desired expansion of the domains of “psychosocial work factors” and “stress” should not occur at the expense of careful considerations of the validity of exposure measures. To ensure comparability across studies as well as conceptual clarity the use of standardized and empirically validated instruments may be important. Furthermore, the need for more systematic considerations of questions relating to the modeling of exposure, especially over time, is warranted. Classification of exposure measures may have profound impacts on the detection of effects. Thus, the current studies have provided useful information and suggest future directions which may further clarify the connection between non-physical aspects of work and perceived physical health.

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